Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

PRICE 2/6

SEPTEMBER 1953

627

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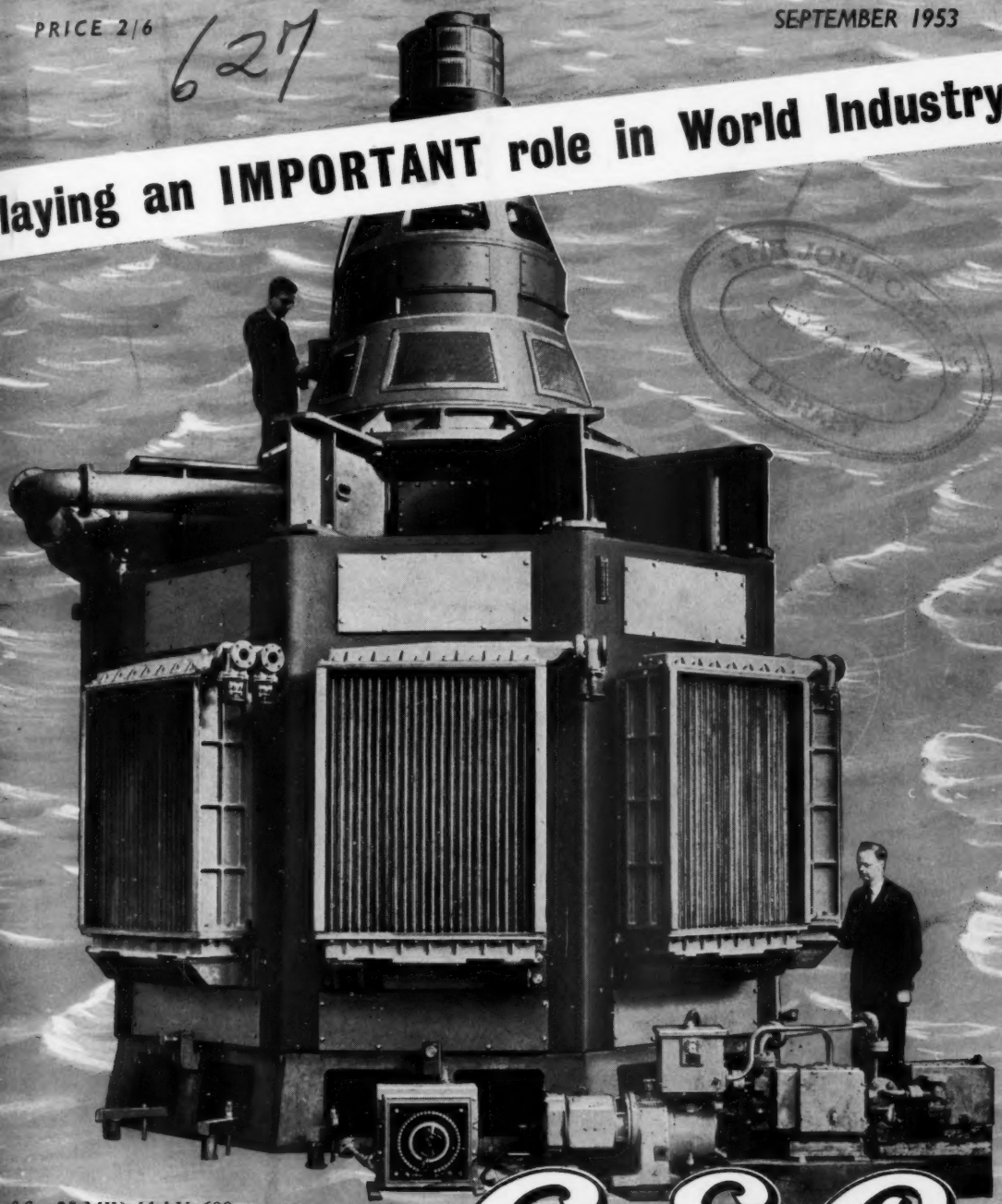
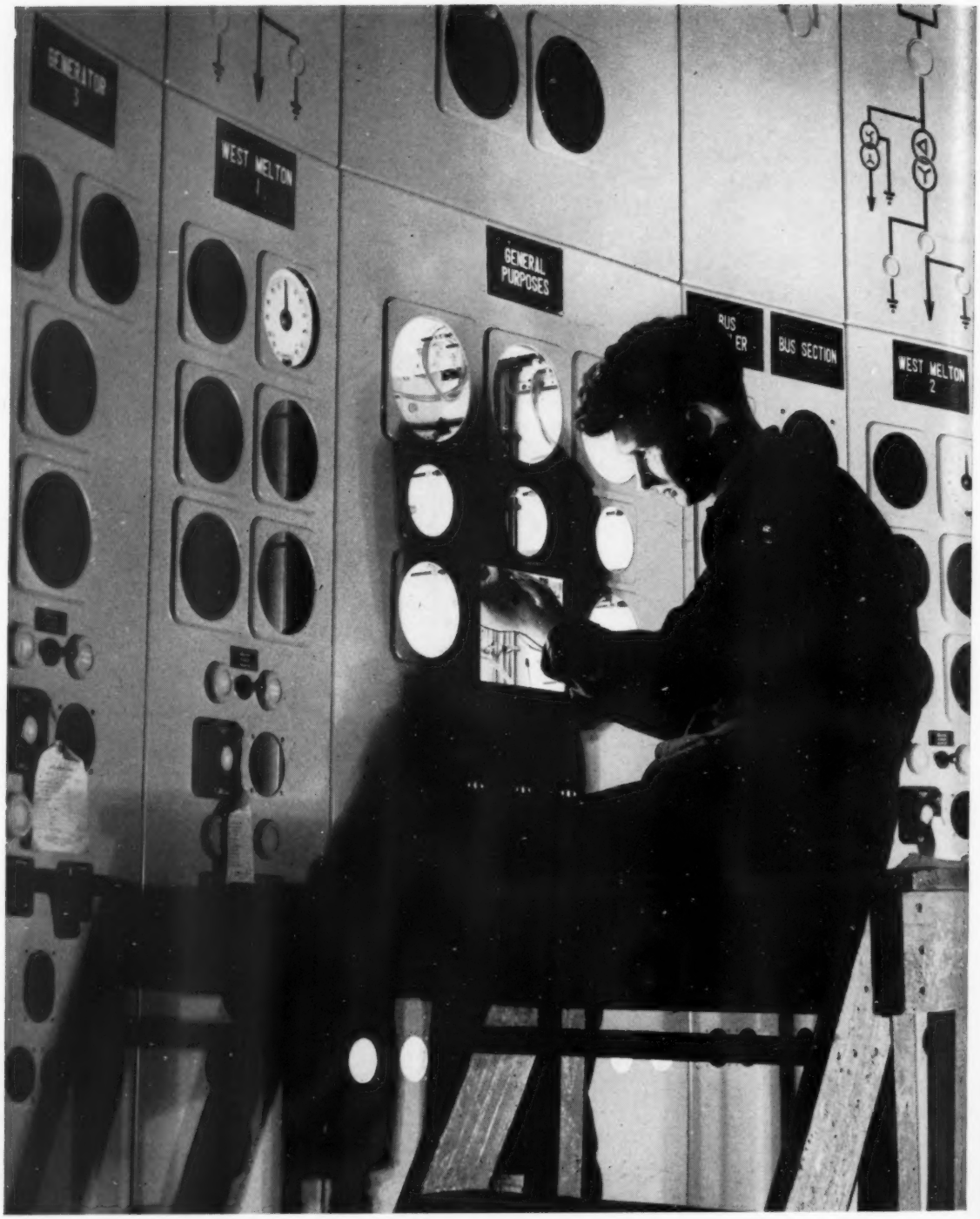


One of five 25 MW, 11 kV, 600 r.p.m. alternators for the Tasmania Hydro Electric Commission.

G.E.C.

HYDRO ELECTRIC PLANT

THE GENERAL ELECTRIC CO. LTD • MAGNET HOUSE • KINGSWAY • LONDON • W.C.2



Control-panels for power-stations

Reyrolle

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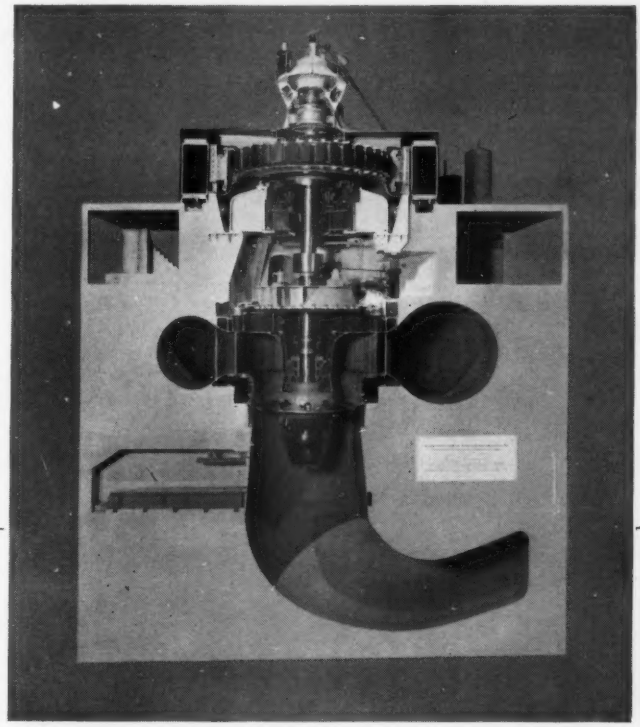
Modern hydro-electric generation



The 'ENGLISH ELECTRIC' plant installed at Tekapo, New Zealand, demonstrates modern hydro-electric generating practice at its best. From the above photograph of a model can be seen many of the finer points. The turbine runner, for instance, has feathering blades and operating gear of 'ENGLISH ELECTRIC' patented design. This gives good efficiency over the wide range of operating head (71 to 96 feet, net) at Tekapo. The main generator is of the vertical shaft "umbrella" type — maximum continuous rating 28,000 kVA, 25,200 kW at 0·9 power factor, 11,000 volts 3-phase 50 cycles. It runs at 150 r.p.m. and a feature is the one combined thrust and guide bearing.

'ENGLISH ELECTRIC'

water power

ENGINEERING, MARINE & WELDING EXHIBITION: OLYMPIA—SEPT. 3rd - 17th—Visit our Stands

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Hydro-electric Department, Stafford

WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

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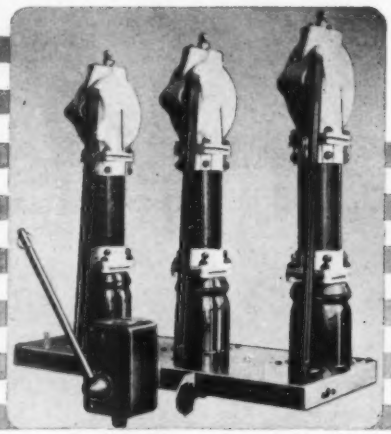
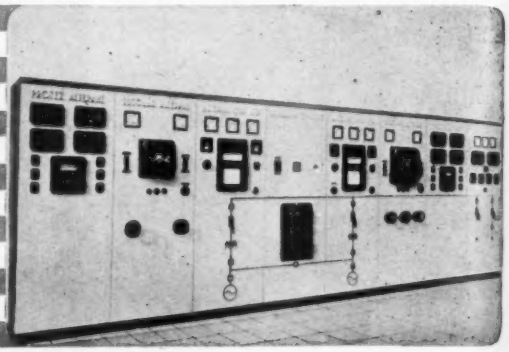
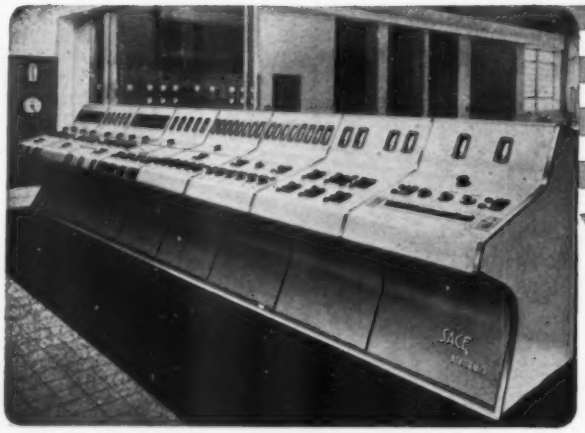


Industrial Plants
Shipboard Plants
Substations
Power Stations





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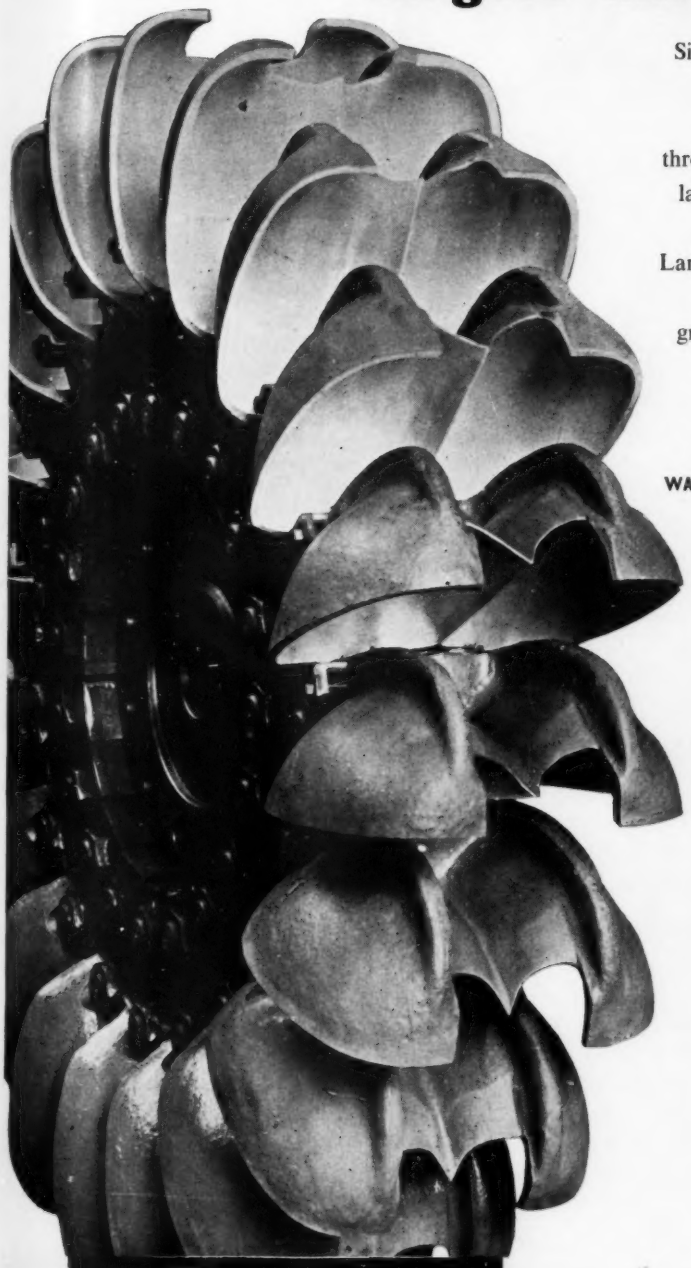
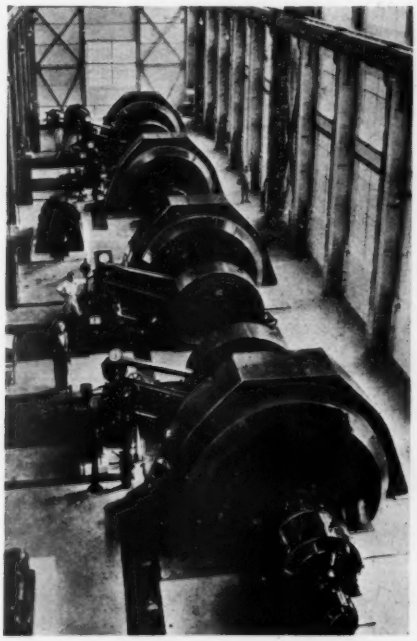
peltons for the highest heads
largest units for least cost



Since 1910 Boving have been manufacturing Pelton turbines and their wide experience on major hydro-electric schemes throughout the world coupled with intensive laboratory tests have enabled a continuous increase to be made in the size of units. Larger units mean fewer per station—lower maintenance—high efficiency, permitting great saving in overall capital cost. Nearly a million horsepower of Boving British built Pelton turbines are in operation throughout the world.

WATER TURBINES · PULP & PAPER MACHINERY, ETC.



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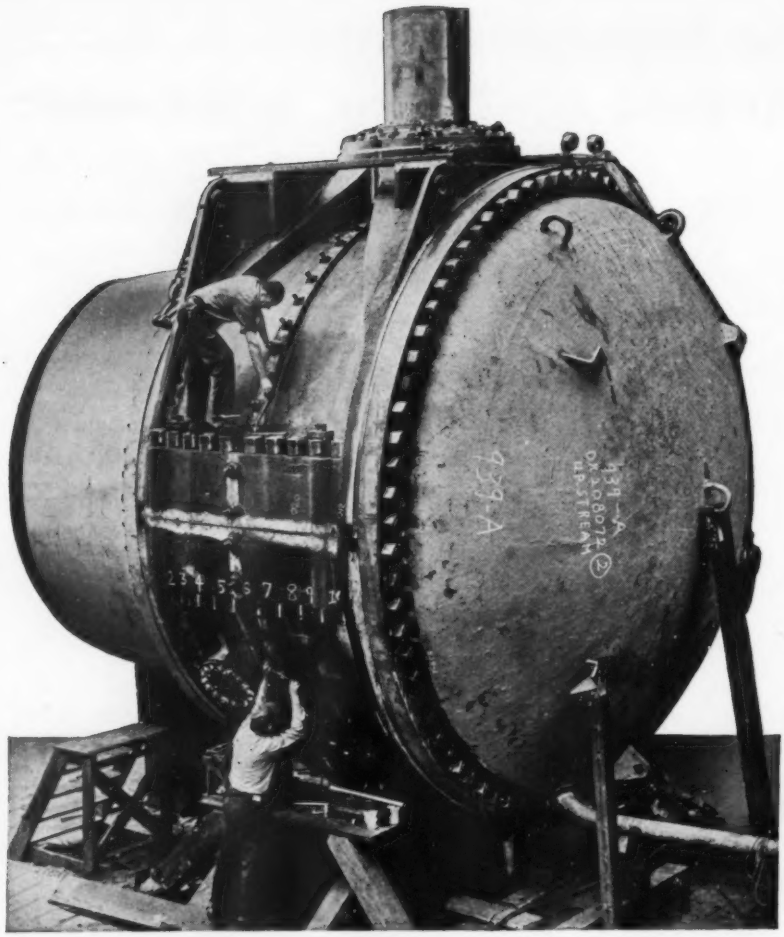

This 16-Foot Butterfly Valve Illustrates the type of work which Newport News takes in stride. Newport News built 3 such valves, each weighing 446,000 lbs., for the Ross Power Plant, Skagit Project, Department of Light, City of Seattle, Washington. Designed for a water flow of 3,620 cu. ft. per sec., and a hydrostatic pressure of 290 psi., these valves were shop tested by Newport News at 450 psi. They are hydraulically operated with oil at 1,500 psi. pressure. Shop tests assure speedy, trouble-free assembly of Newport News built equipment, on the site.

The TEST of a TITAN

Here is one of the largest high head butterfly valves ever built, undergoing a shop test at Newport News. If you had an opportunity to follow this unit from start to finish, you would see *first hand* how Newport News produces massive equipment *economically*. For economy is a basic advantage that results from Newport News' high integration of skill and production facilities.

Large engineering and technical staffs, operating a plant comprising acres of brass, iron and steel foundries, five huge machine shops and other extensive fabricating facilities, have made Newport News one of the world's largest producers of hydraulic turbines, valves, gates, penstocks and other essential equipment... both standard and special in design.

Let us bid on your equipment. Write us today for your copy of *"Water Power Equipment."*

NEWPORT NEWS

SHIPBUILDING AND DRY DOCK COMPANY
Newport News, Virginia

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FOR
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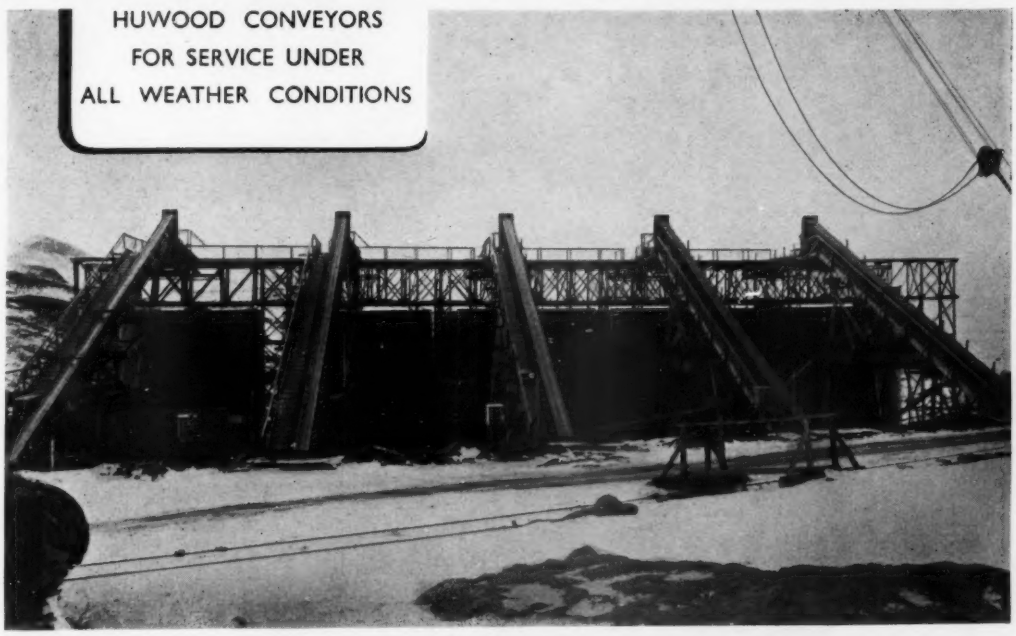

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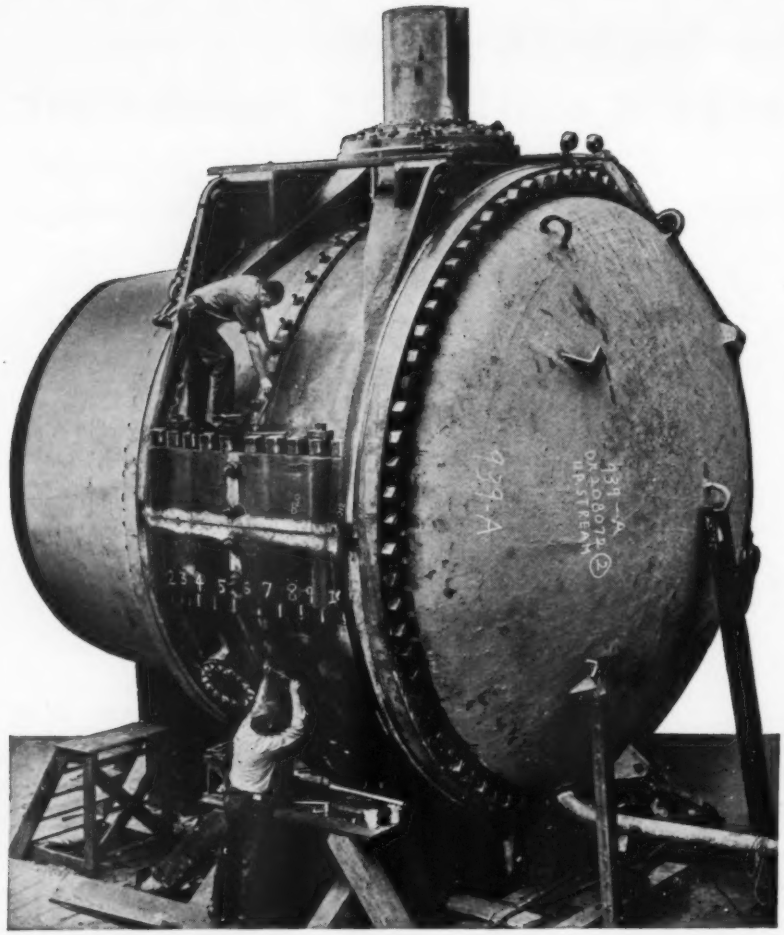

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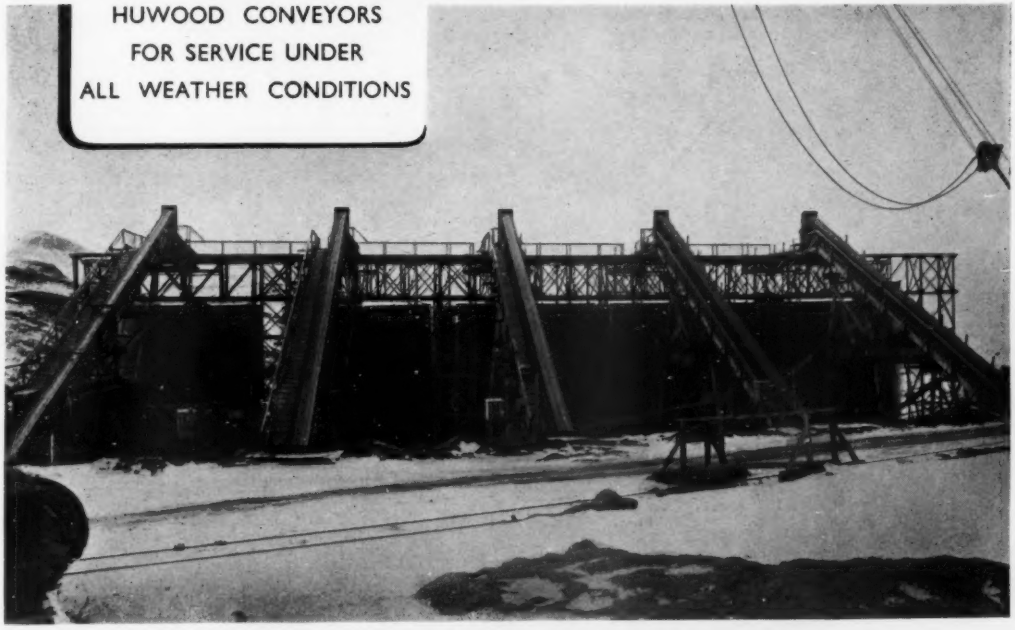

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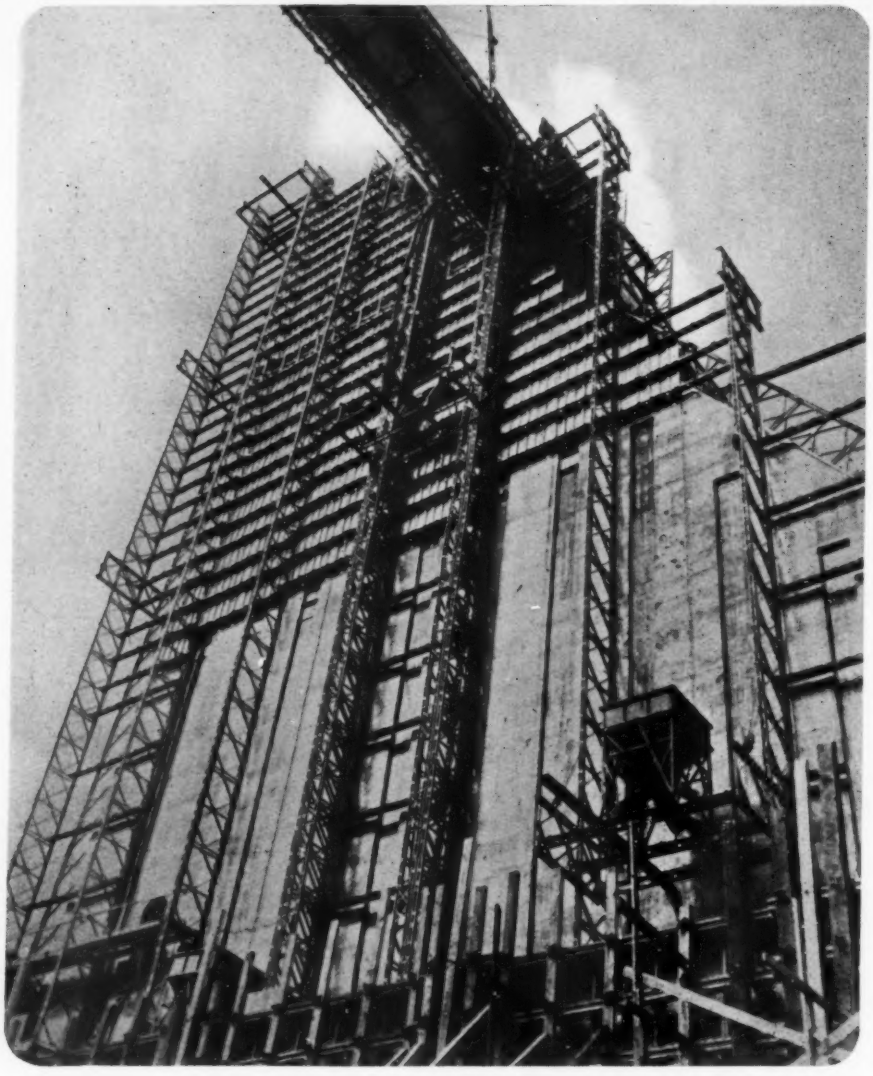

Photograph by courtesy of the Ontario Hydro Electric Commission

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Engineers throughout the world, engaged on major projects to harness natural resources, combine the structural and mechanical aids of Bailey Bridging with their technical and productive skill. To-day's tremendous speed of construction demands Bailey Bridging equipment which fulfils all requirements, regardless of magnitude. Our organization is privileged to place at your disposal a world-wide technical and Bailey Bridging supply service, unique in Civil Engineering.

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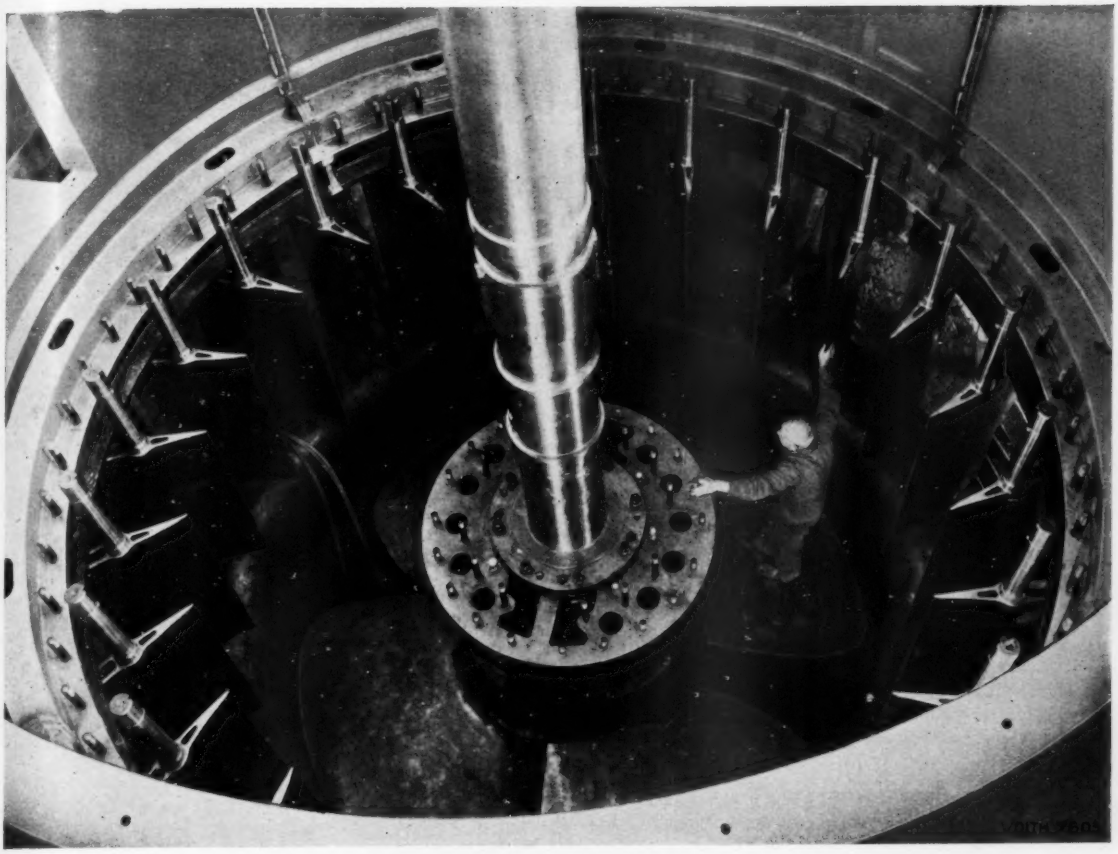
Voith Hydraulic Turbines

and Accessories for Water Power Plants



Erection of a 5650 H.P. Kaplan Turbine

Kaplan Turbines for low or high heads

We have under construction :

For Hydro Power Station	Number of Turbines	Dia. of Runner Ft.	Head Ft.	Capacity each H.P.
Hirakud II, India	2	14·7	78	34100
Pathri, India	3	12·8	32	9500
Simbach-Braunau, Germany/Austria	4	20·4	40	32700
Jochenstein, Germany/Austria	3	24·3	32	39400
Rosshaupten, Germany	2	11·5	66 to 125	14400 to 33800
Jintsu, Japan	2 + 1 Runner	11·6	102	28500
Tinfoss, Norway	1	11·5	95	26000
Tsunokawa, Japan	1	8·3	120	13000

J.M. Voith G.m.b.H., Engineering Works, Heidenheim (Brenz)

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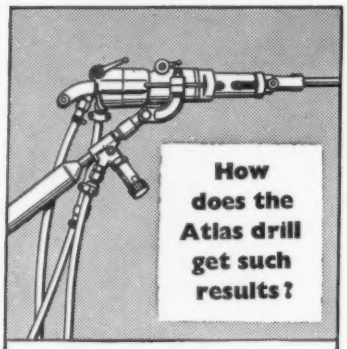


How does the Atlas drill get such results?

It's light—drill and pneumatic pusher: 88 lbs.

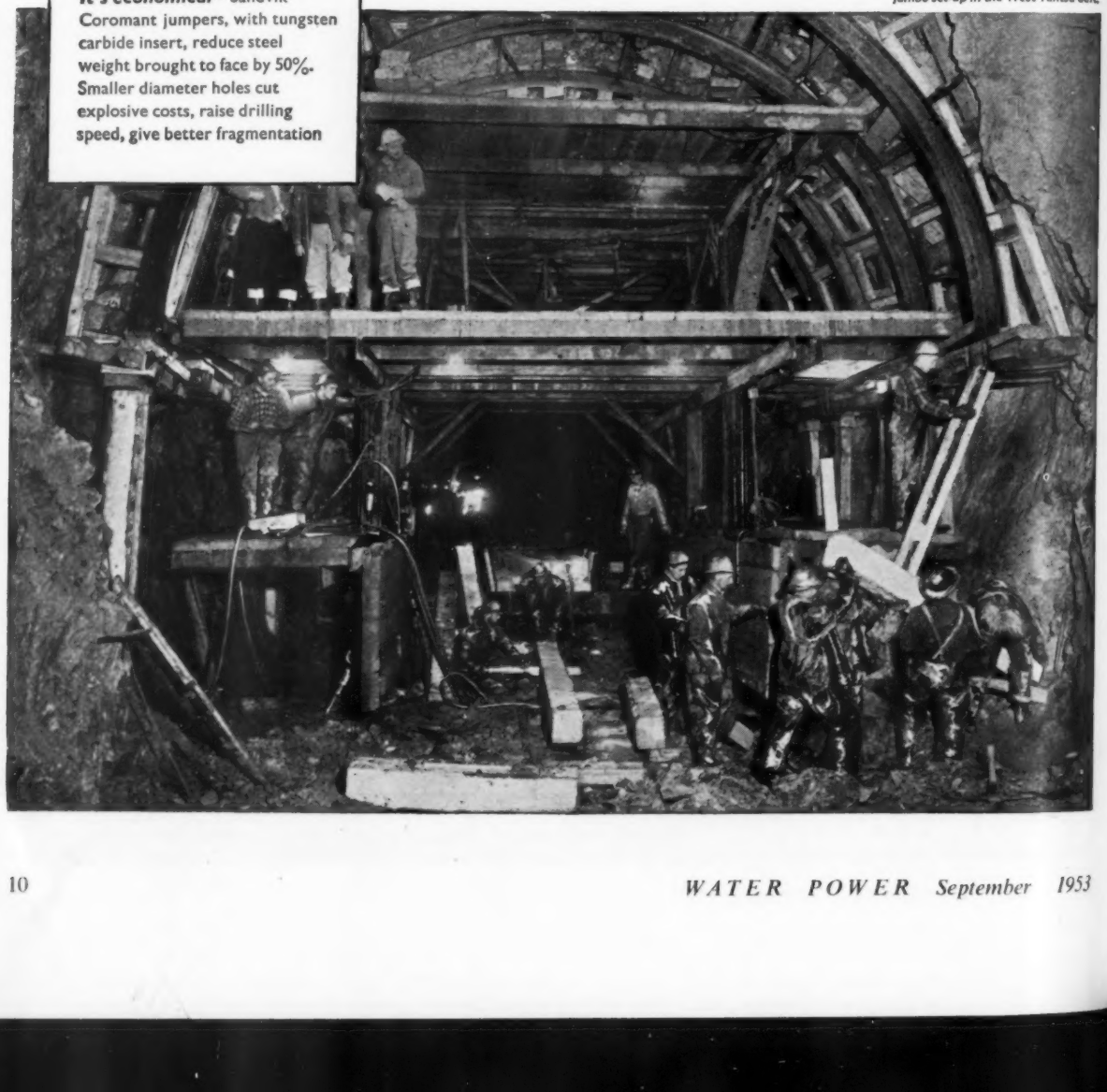
It's fast—set up time: 3-7 minutes by one man. 70% to 80% of all time at the face is spent in drilling.

It's economical—Sandvik Coromant jumpers, with tungsten carbide insert, reduce steel weight brought to face by 50%. Smaller diameter holes cut explosive costs, raise drilling speed, give better fragmentation

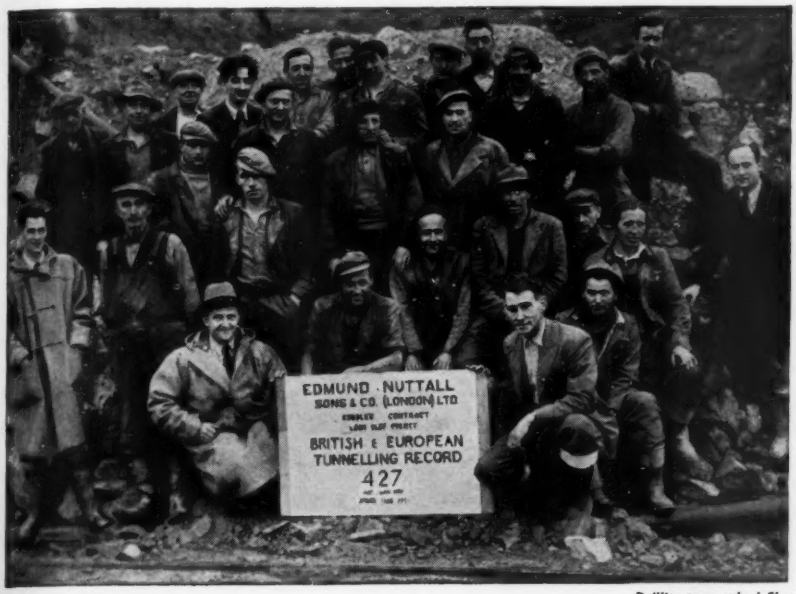
14 Atlas drills take out 4,080 cu. yds. in one week

At the vast Alcan hydro-electric project, only 14 lightweight Atlas drills were needed to drive the West Tahtsa section of the 20 ft. diameter hydraulic pressure tunnel. Average advance per day for a six day period was 45·3 ft. through block porphyrys and andesites. *Fourteen drillers & a supporting crew of nine removed 4,080 cu. yds. in a week.*

Jumbo set-up in the West Tahtsa adit.



In Scotland —



Drilling team at Loch Sloy

Atlas drills hold British tunnelling record

At the Loch Sloy project, part of the North of Scotland hydro-electric scheme, Atlas drills drove 7 x 7 ft. tunnel 427 feet through hard diorite in a single week. For the Contractors, Edmund Nuttall, Sons & Co. (London) Ltd, the second tunnelling record inside three months!

AND NOW—

anywhere in Great Britain —

we'll send a team to show you how it's done!

Anywhere in Great Britain where rock drilling is in progress — at any time you like to arrange — Atlas Diesel will send a demonstration team to show what the light Atlas Drill can do. We can *prove* that Atlas drills can do on your job what they're doing all over the world — break more rock more quickly at less net cost per cubic yard. *Write our Head Office and make a date for a demonstration.*

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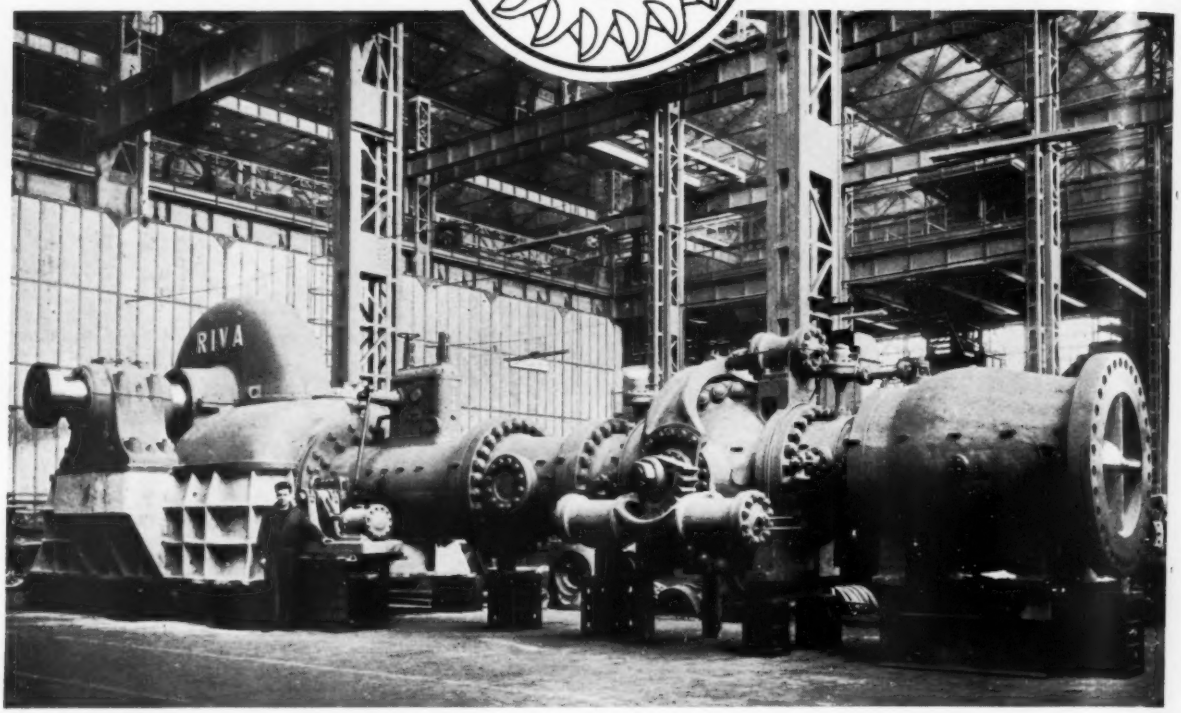
PELTON RIVA TURBINES



62,000 H.P. Single Runner Single Jet Riva Impulse Turbine

The Turbine Unit illustrated is now in course of being installed at the Avise Power Station, Italy, and is one of two such Units designed and constructed by Riva for the Societa Idroelettrica Piemonte, Turin.

The Turbines are fitted with the Riva patent straight flow Nozzle, Riva patent spherical valve, and an axial emergency valve.

It is believed these are the highest powered Single Runner, Single Jet Turbines that have yet been built.

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Sole Representatives for UNITED KINGDOM, CANADA, TASMANIA, SOUTH AFRICA, SOUTHERN RHODESIA, CEYLON, PAKISTAN, AND ALL BRITISH COLONIES AND THE REPUBLIC OF EIRE

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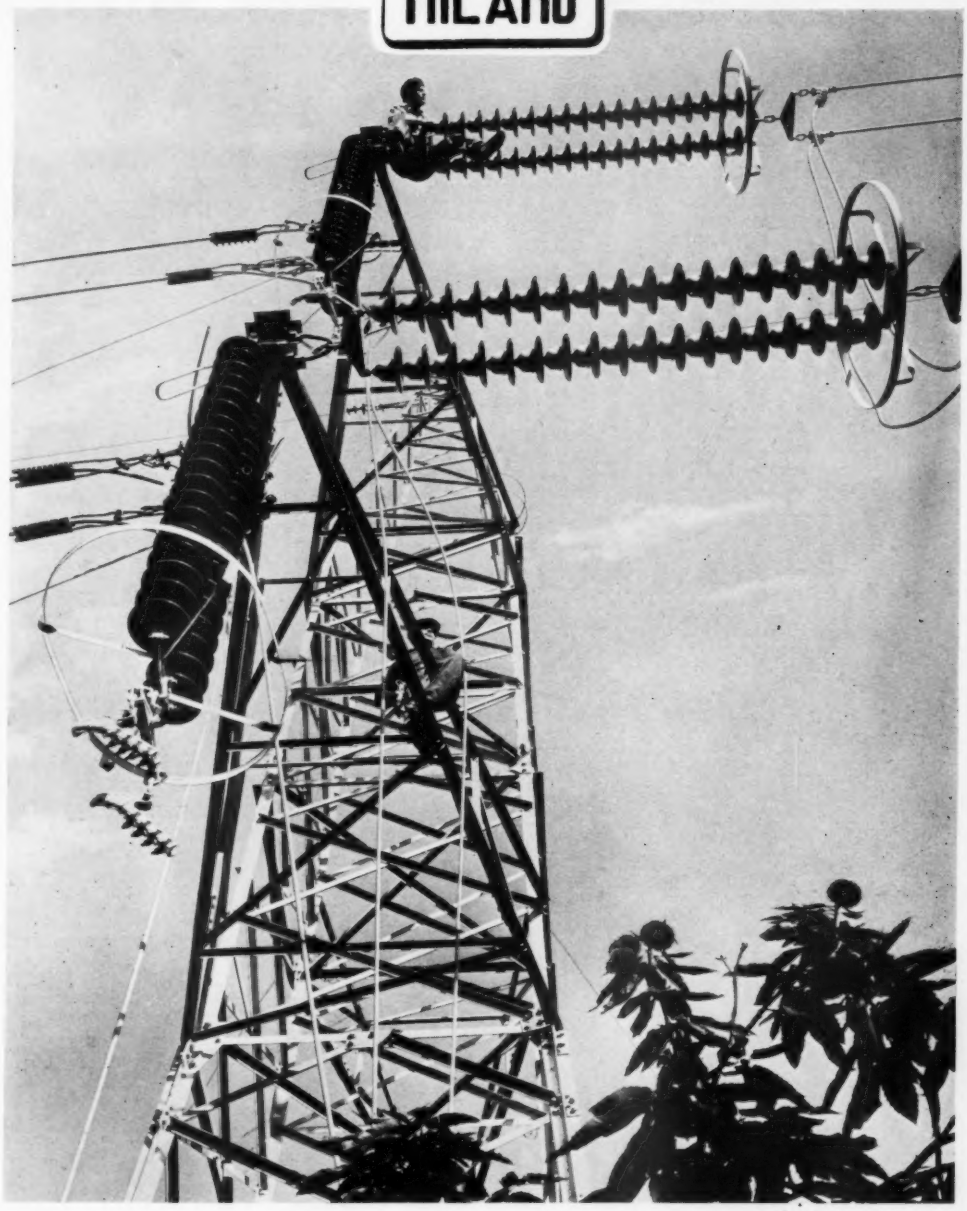
HIGH VOLTAGE SALVI IFI MILANO LINE FITTINGS



3-230 kV Villa Valle-Cornegliano 4 Twin S.C.A. Conductor Transmission Line (Societa TERNI-Rome)

For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialised in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints. Suspension and Strain Clamps. Arcing Horns. Guard Rings. Shackles. Armour Rods. Galvanized Bolts and Nuts, etc.

The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including pressures of 220/380 KV, and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

We shall be glad to receive enquiries and to provide a data sheet indicating the details we require to enable us to quote for your requirements.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES AND BRITISH COLONIES AND PROTECTORATES

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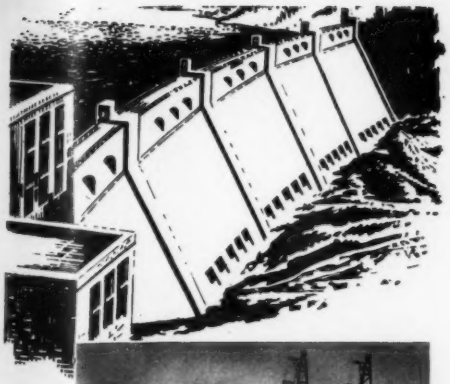
KMW

The runner is cast in one piece and made of stainless steel. The design of our runners is based on extensive hydraulic research in our laboratories.

A turbine under erection in our works for pressure testing and strain gauge measurements of the parts that are vital for the strength of the machinery.

AKTIEBOLAGET KARLSTADS MEKANISKA WERKSTAD

Karlstad . Sweden



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Specially designed for the handling of materials on large-scale construction projects, HENDERSON Aerial Cableways are used in all parts of the world . . . they are found to move bigger loads faster and at lower cost. Low cost materials handling is the key to successful civil engineering undertakings—and wherever there is a dam or barrage, a bridge or viaduct to be built, a Henderson Cableway more often than not will be found to be the most practical means of construction.

FAST · RELIABLE · ECONOMICAL

Henderson

CABLEWAYS ARE ESSENTIAL ON ALL LARGE-SCALE CONSTRUCTION PROJECTS

JOHN M HENDERSON AND CO LTD KING'S WORKS ABERDEEN

LEADERS IN CABLEWAY DESIGN & CONSTRUCTION

An OUTDOOR Circuit Breaker

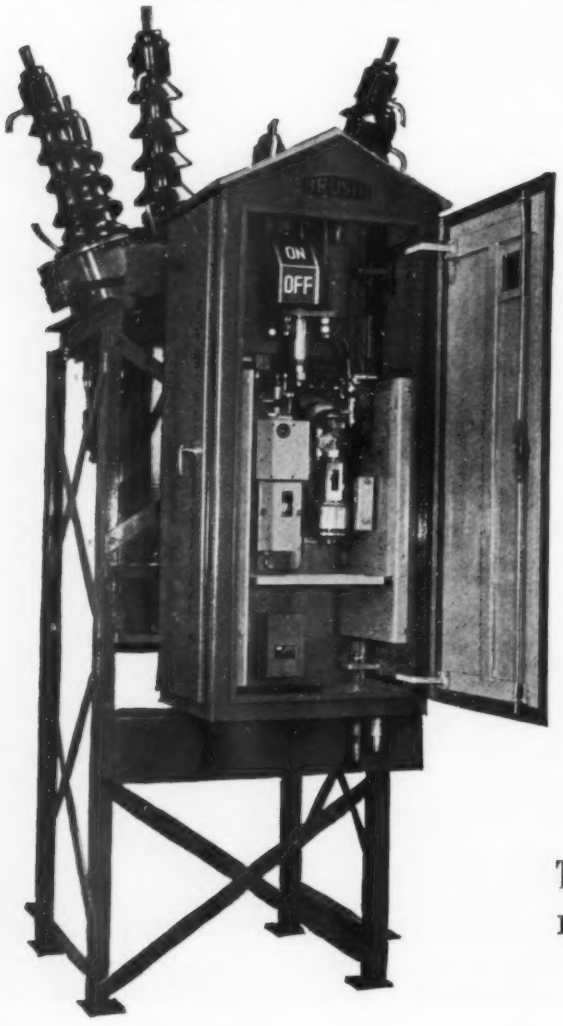
(pneumo-hydraulically operated)

IN THE DESIGN of this bulk-oil Circuit Breaker the mechanical construction is simple and generous to ensure permanently satisfactory performance under the most arduous conditions of service.

Built to comply with British Standard 116-1937 (Part 2) it has been subjected to short circuit test and certified for the rating assigned—i.e. 1,000 amps.—750 MVA Breaking Capacity—33 and 38.5 kV.

The illustration left shows a circuit breaker fitted with apparatus for pneumo-hydraulic operation. The circuit breaker may be closed four times in succession without recourse to auxiliary power supply.

As an alternative BRUSH Outdoor Circuit Breakers can be fitted with Solenoid Operating Mechanism.



For full information write TODAY for our NEW Publication No. 41166/A.

BRUSH 33/38.5 kV

Oil Circuit Breakers

THE BRUSH ELECTRICAL ENGINEERING CO. LTD.

LOUGHBOROUGH, ENGLAND

B18

ESCHER WYSS ZURICH

Escher Wyss has developed to a very high degree the design and manufacture of high-head Francis turbines. The above runner is that of a turbine developing 65,000 h.p. under a head of 1,050 ft. Similar turbines, but for larger outputs and heads, are in course of construction.

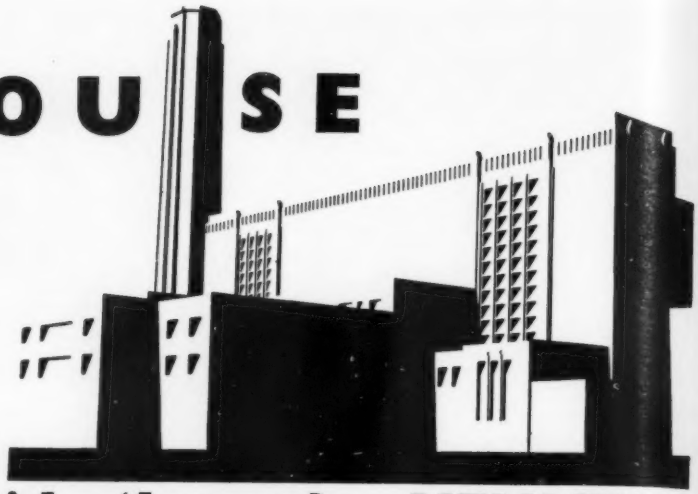
We further specialize in Kaplan and impulse turbines up to the largest outputs and heads, as also in large storage pumps and other hydraulic equipment.

Our experience in manufacture and in installation work all over the world is at your disposal.

ESCHER WYSS LTD., ZURICH (SWITZERLAND)

RYE HOUSE

Two important contracts carried out recently provide circuits for connecting the B.E.A. Eastern Division's fine new generating station at Rye House, Hertfordshire, to the Grid.



feeds the Grid through HENLEY Overhead Lines and Cables

The installations by Henley's Contract Department shown here are the Rye House-Hatfield-Watford 132-kV line at Elstree, and a joint bay with Henley 33-kV oil-filled cables.

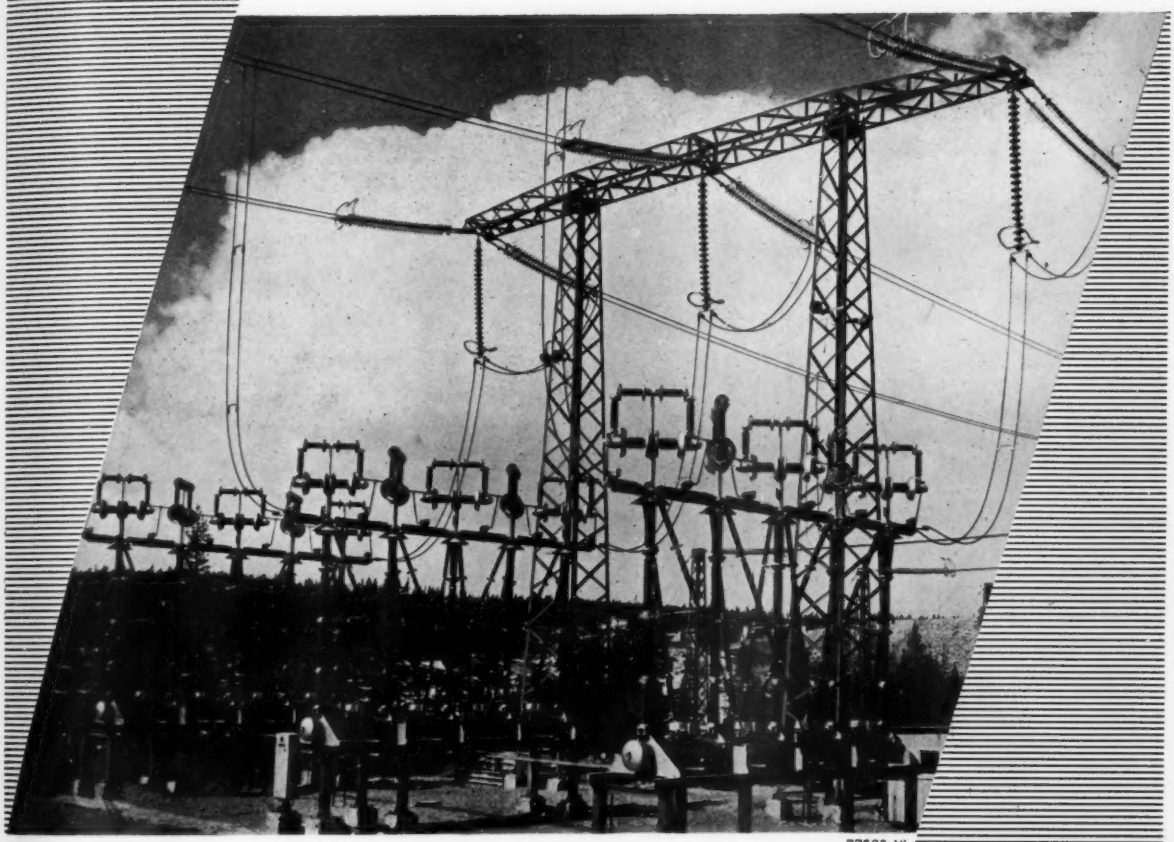
BY APPOINTMENT ELECTRIC CABLE MANUFACTURERS TO THE LATE KING GEORGE VI

HENLEY CABLES

W. T. Henley's Telegraph Works Co. Ltd.
51-53 Hatton Garden, London, E.C.1

BROWN BOVERI

400 kV



77623·VI

Brown Boveri 400-kV air-blast circuit-breaker in Harspränget power station (Sweden).

Ten of these circuit-breakers have been ordered for the world's first 380-kV system in Sweden. The first was commissioned in May, 1952, and field acceptance tests proved that the severest conditions can be coped with.

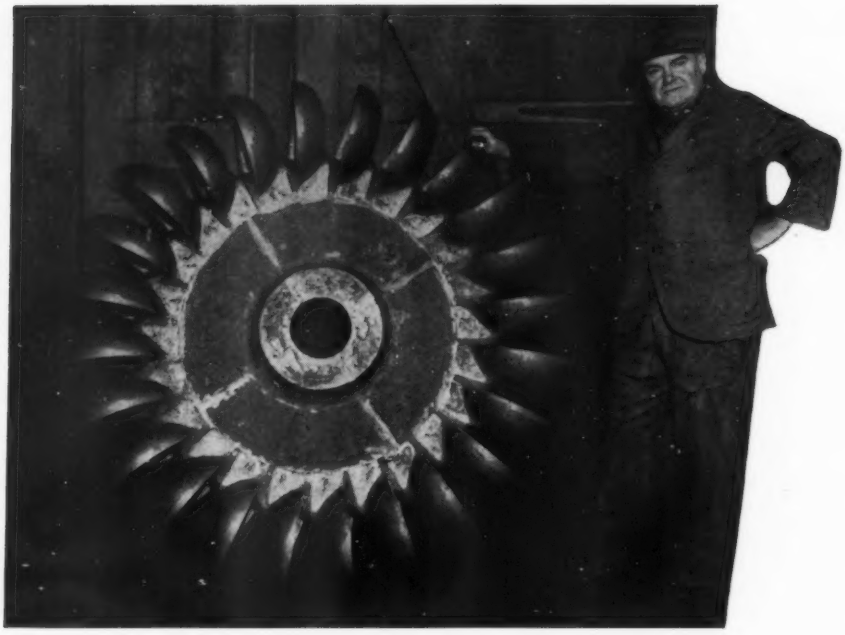
We build air-blast circuit-breakers assembled from proved standardised units manufactured on batch-production lines, for voltages up to 400 kV, and symmetrical breaking capacities up to 8,600 MVA.

Advantages: Short breaking time, high breaking capacity, suitable for single- or three-phase reclosing, simple erection, light weight, no inflammable oil.

BROWN, BOVERI & CO., LTD., BADEN (SWITZERLAND)

Aluminium Bronze

—for rugged dependability



Aluminium Bronze Runner Casting supplied to Messrs. Gilbert Gilkes & Gordon Ltd., Kendal, for a 750 H.P. Pelton Wheel. This is for one of two similar turbines which will be installed at the Kilembe Copper Mines, Uganda.

NON-FERROUS CASTINGS
MACHINED PARTS
CHILL-CAST RODS & TUBES

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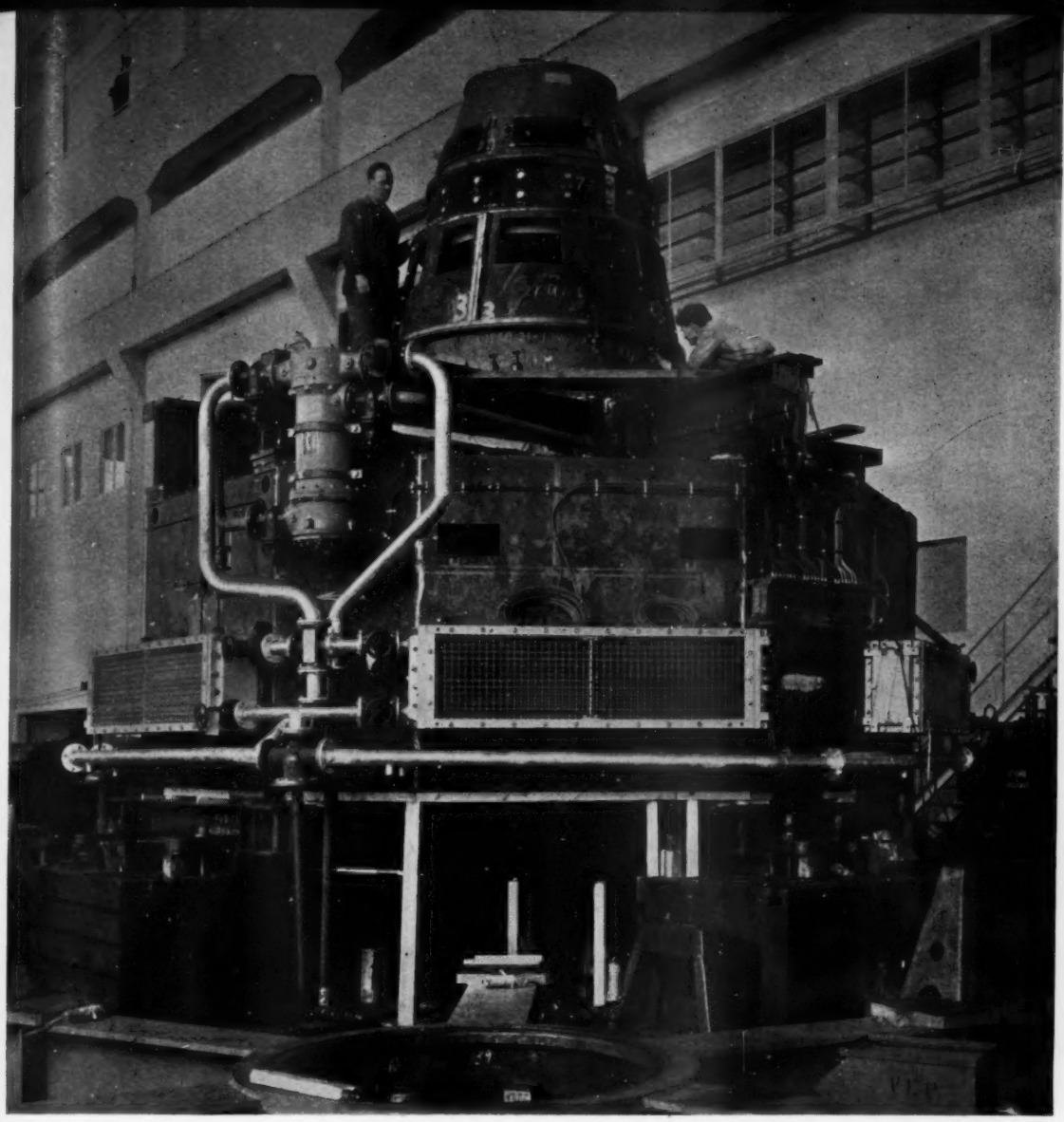


UNIÓN ELÉCTRIA MADRILEÑA

—one of Spain's largest producers of electric power, whose power stations had a combined output approximately 135,000 kVA at the end of 1952, has now embarked upon a comprehensive construction programme to extend its output by 170,000 kVA. ASEA is now supplying the three new Entrepeñas, Buendía and San Juan power stations of the organisation with

7 VERTICAL A.C. GENERATORS

each with a rating of 19,000 kVA at 11 kV, 250 r/m, 50 c/s, making, in all

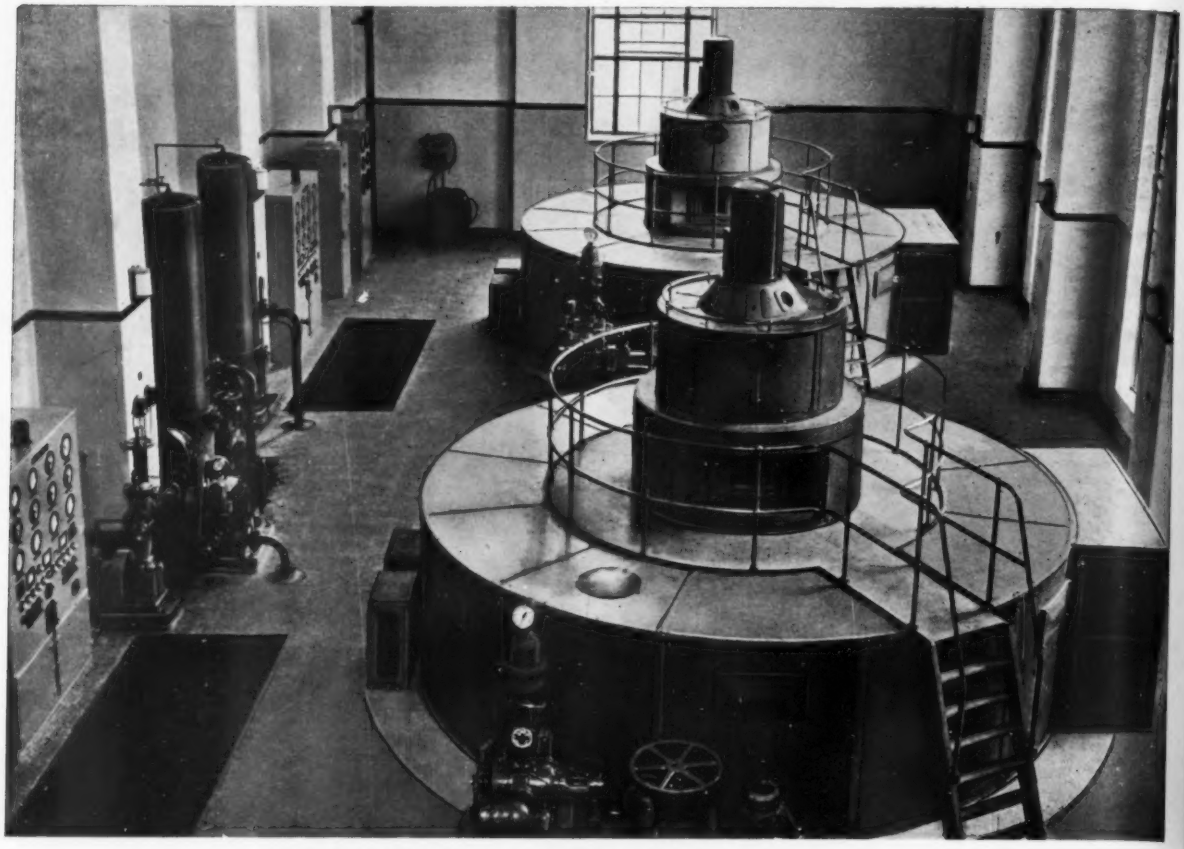
133,000 kVA

In addition, ASEA is supplying complete control equipments and switchgear for all three stations.

To-day as ever ASEA stands in the front rank in the development of electrical power engineering and our manufacturing programme covers every aspect of the heavy electrical industry.

Consult us for expert advice on all questions concerning power plant projects.

Västerås **ASEA** Sweden

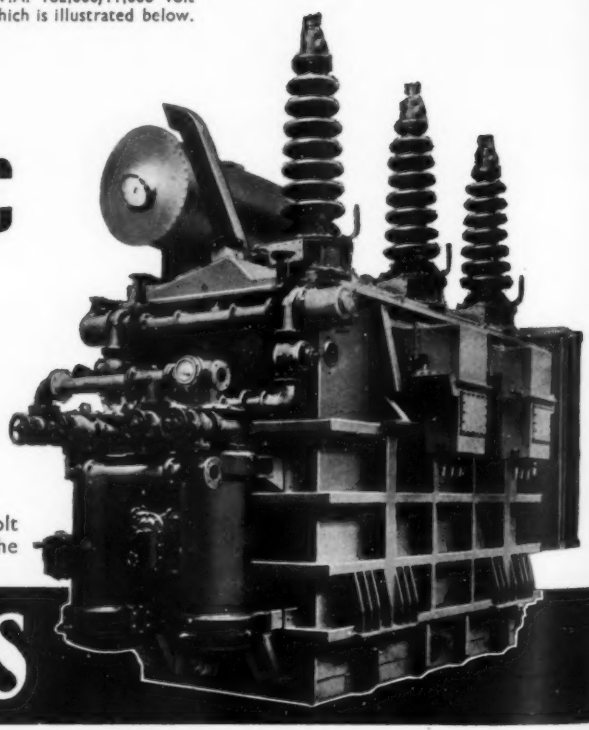


LOCH FANNICH PROJECT, North of Scotland Hydro-Electric Board. View of Grudie Bridge power station showing two 12,000 K.W. 11,000 volt, 500 r.p.m. vertical generators. The installation includes two 20,000 K.V.A. 132,000/11,000 volt water-cooled transformers, one of which is illustrated below.

PEEBLES

hydro-electric plant

Bruce Peebles build large and small generators for all types of water turbines, and transformers up to the largest sizes for hydro-electric power distribution.

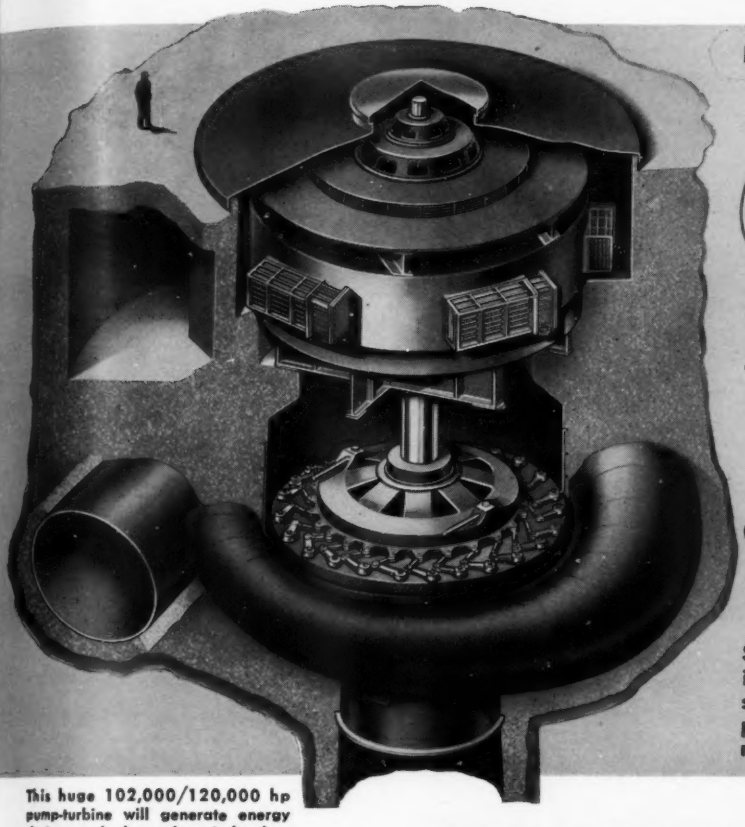


20,000 kVA. 132,000/11,000 volt water-cooled transformer for the Loch Fannich scheme.

BRUCE PEEBLES

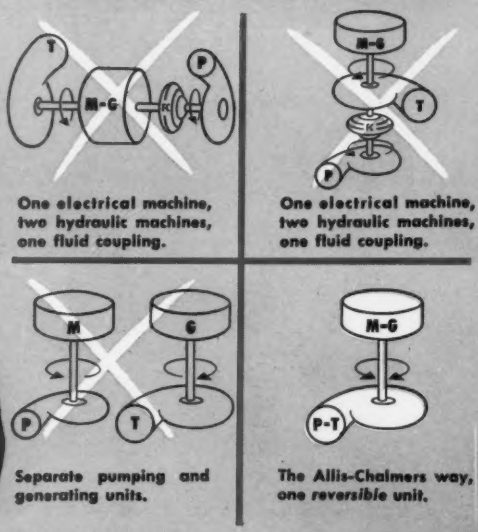
Advertisement of BRUCE PEEBLES & CO. LTD. · ENGINEERS · EDINBURGH · SCOTLAND 3974

ALLIS-CHALMERS Pioneers *REVERSIBLE* Pump-Turbines!



This huge 102,000/120,000 hp pump-turbine will generate energy during peak demand periods, then reverse and — using surplus power from other plants — restore water to the reservoir during off-peak periods. Power value differential will make operation economical.

HOW REVERSIBLE PUMP-TURBINE REDUCES EQUIPMENT NEED



Sketches above show different methods of applying motive and generating equipment for pumped storage. Note that the Allis-Chalmers reversible pump-turbine at lower right requires least equipment and simplest power plant construction.

NOW BUILDING 5 UNITS FOR PUMPED STORAGE

THIS RECORD SIZE pump-turbine is now under construction by Allis-Chalmers for the Hiwassee dam in North Carolina. It combines in one reversible, two-element unit an electrical machine rated 102,000 hp as the world's largest motor and a hydraulic machine with the world's largest Francis runner.

When operating at maximum head as a turbine, this reversible unit will develop 120,000 hp. As a pump, it will move a maximum of 5200 cfs, 3.3 billion gallons per day . . . three times the capacity of the largest existing pump.

Allis-Chalmers — builder of over 12 millions of installed hydraulic horsepower — pioneered the development of the reversible pump-turbine for pumped storage. A-C offers you undivided responsibility, being able to design and build *all* elements of an entire reversible pump-turbine unit.

Of the five reversible pump-turbines A-C is now building, the Hiwassee unit is the largest. First scheduled for service is the 12,650 hp unit for the Flatiron Power & Pumping plant in Colorado. Three 19,000 hp units for the Sao Paulo Light & Power Co., Ltd., Brazil are now being built at Canadian Allis-Chalmers, Ltd., Montreal.

You get the real design advances *first* from Allis-Chalmers. And dealing with A-C is convenient, too, with 95 sales offices and 65 distributors located in 53 countries. For your free copies of Reversible Pump-Turbine Bulletin 01R7784 and illustrated, 56-page Bulletin 02B7301 of world famous hydro plants, just call your nearest A-C distributor or write to Allis-Chalmers, Milwaukee 1, Wisconsin, U.S.A. A-4011

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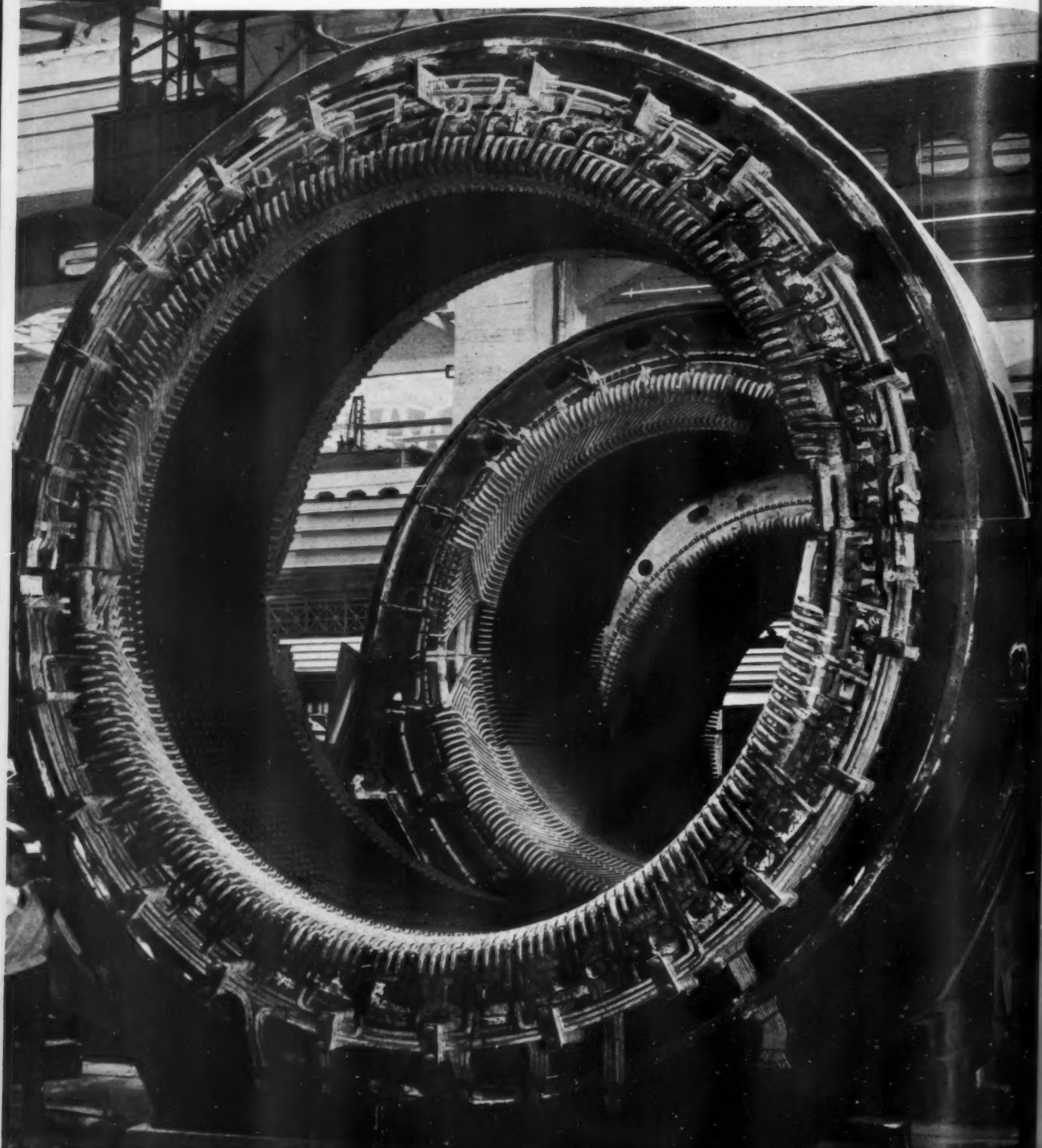

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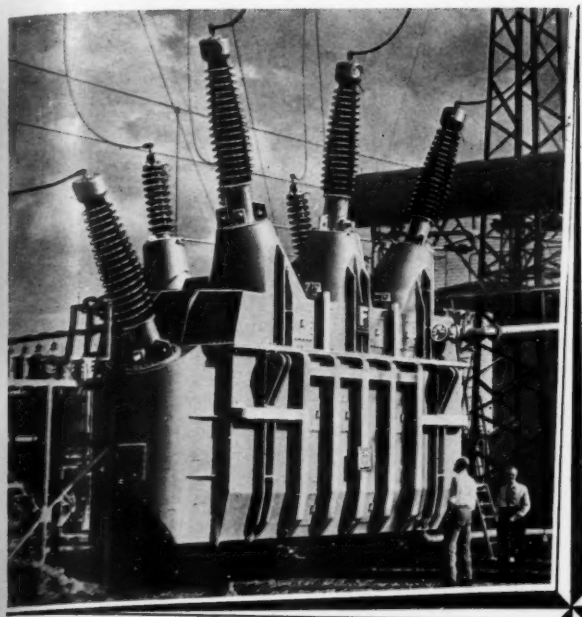
FERRANTI *in the east and in the west*



FINLAND

PYHÄKOSKI AND HIKIA GENERATING STATIONS

Ferranti Ltd. have supplied, or have under construction, six 230 kV three-phase transformers for the Imatra Power Company, Finland, the first two of which were the first 230 kV three-phase transformers to be ordered in Great Britain. Each transformer is rated at 64/64/32 MVA, 231/115.5/10.5 kV, and has a total weight with cooling gear of 220 tons.

Opposite: One of the completed transformers in commission at the Pyhäkoski Generating Station.

UNITED STATES

GARRISON DAM PROJECT

N. DAKOTA

Through Ferranti Electric Inc., New York, the Ferranti organisation has secured in open competition the contract to supply the U.S. Army Corps of Engineers with nine single-phase 13.2/230 kV, 33,333 kVA generator transformers, forming three 3-phase 100,000 kVA banks, each bank connected to the 13.8 kV output of one 80,000 kVA hydroelectric generator with a maximum continuous rating of 97,800 kVA.

CANADA

ALCAN BRITISH COLUMBIA PROJECT

Ferranti transformers ordered for this project comprise four 71,000 kVA single-phase generator transformers forming a 213,000 kVA, 13,200/301,000 volt 3-phase bank at KEMANO and three 37,000 kVA, single-phase step-down transformers at KITIMAT, will form a 111,000 kVA, 275,000/13,200 volt 3-phase bank. The contract was secured against international competition.

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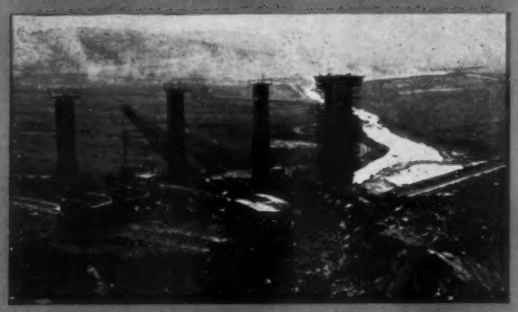
FERRANTI – A FAMOUS NAME IN ELECTRICAL ENGINEERING FOR 70 YEARS

FT128

'five years hard'

Twenty-four Aveling-Barford 4½ cu. yd. Shuttle Dumpers, some of which have logged over 8,000 working hours, are making a big contribution to the construction of the Daer Valley dam, some 45 miles south of Glasgow. These machines have been used right from the start — nearly five years ago — when they assisted in stripping the area of 350,000 cubic yards of peat. Since then they have been used continuously for transporting concrete aggregates, mixed concrete and excavated rock. Their day in, day out reliability and outstanding manœuvrability has done much to speed the completion of this important project.

Write for Publication No. 1529/124.



The spillway head of the Daer Valley dam — the largest of its type in Britain — with the projected reservoir in the background.

AVELING-BARFORD

4½ YARD DUMPER

Photographs by courtesy of the Daer Water Board and Messrs. Binnie, Deacon and Gourley, Consulting Engineers.

AVELING-BARFORD LTD GRANTHAM ENGLAND

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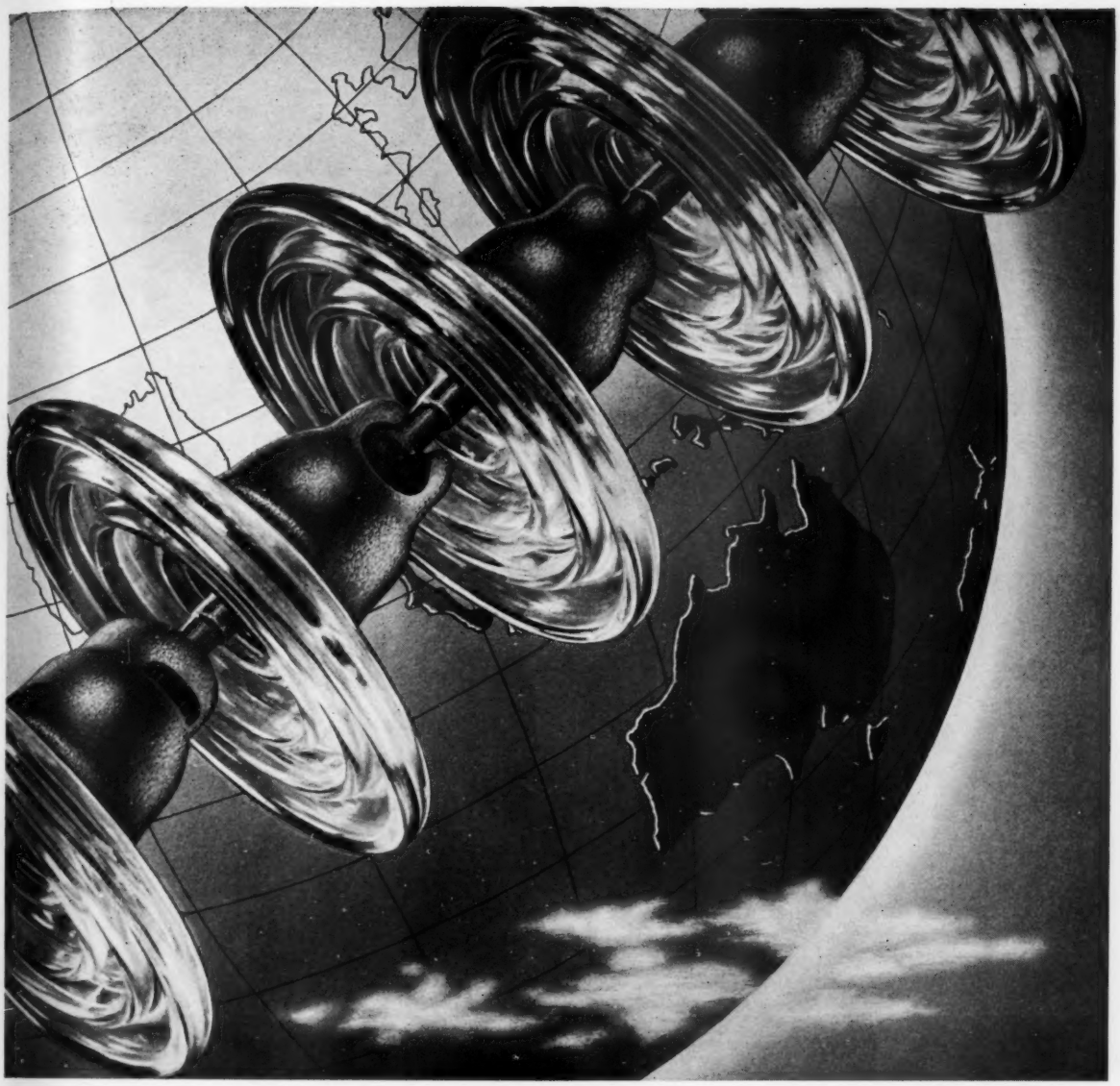

Nearly a million in Australasia

In the past few years millions of "ARMOURLIGHT" Toughened Glass Insulators have gone into service throughout the world—nearly a million in Australasia; over a million in Africa; 500,000 in other parts of Europe and elsewhere; over two million in the United Kingdom and Eire.

"ARMOURLIGHT" Insulators have an impulse electric strength four or five times greater than porcelain. They are impervious to lightning surges and their resistance to power-arcs is twice that of porcelain. The life of the insulator is that of the metal fittings. Moreover, failure from any cause always results in complete break-up of the glass insulator disc, though not of the metal suspension, and the trouble-spot can be easily seen from ground level or from a low-flying aircraft.

For technical advice and literature, write to Pilkington Brothers Limited, Insulator Sales Department, Ravenhead Works, St. Helens, Lancs.

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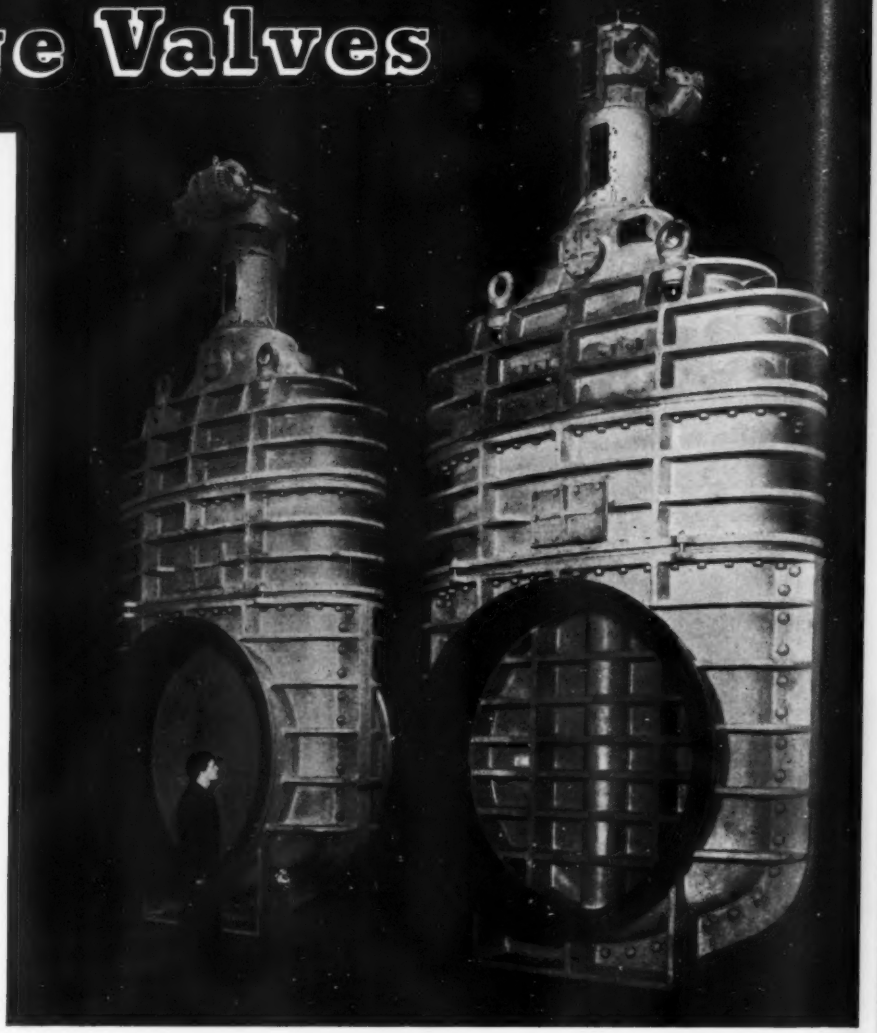
Large Valves



VALVES in the larger sizes call for their own special treatment, and few firms have anything approaching Blakeborough experience in this field. We were manufacturing valves up to 66" diameter nearly 60 years ago, and since then have built up facilities for the production of this class of equipment on an exceptional scale. Sluice valves are available from existing patterns in a full range of sizes up to 96" diameter; needle valves in any required size; penstocks up to the largest in use; etc. Power driven operating gear is arranged to suit requirements.

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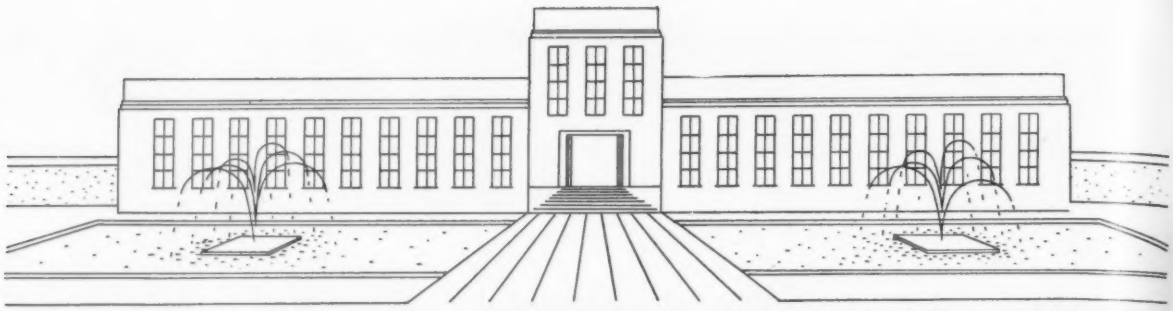

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WATER

Swansea Usk Pipeline Contract. 33½ miles constructed in 6 sections of 28"—27"—26" & 20" pipes. Approximately one-third of the distance is in terrain similar to that pictured above. Other sections include nine under water and eight above water crossings with spans up to 150ft. Constructed for the Swansea Corporation Water Department.

Consulting Engineers: Binnie, Deacon & Gourley.

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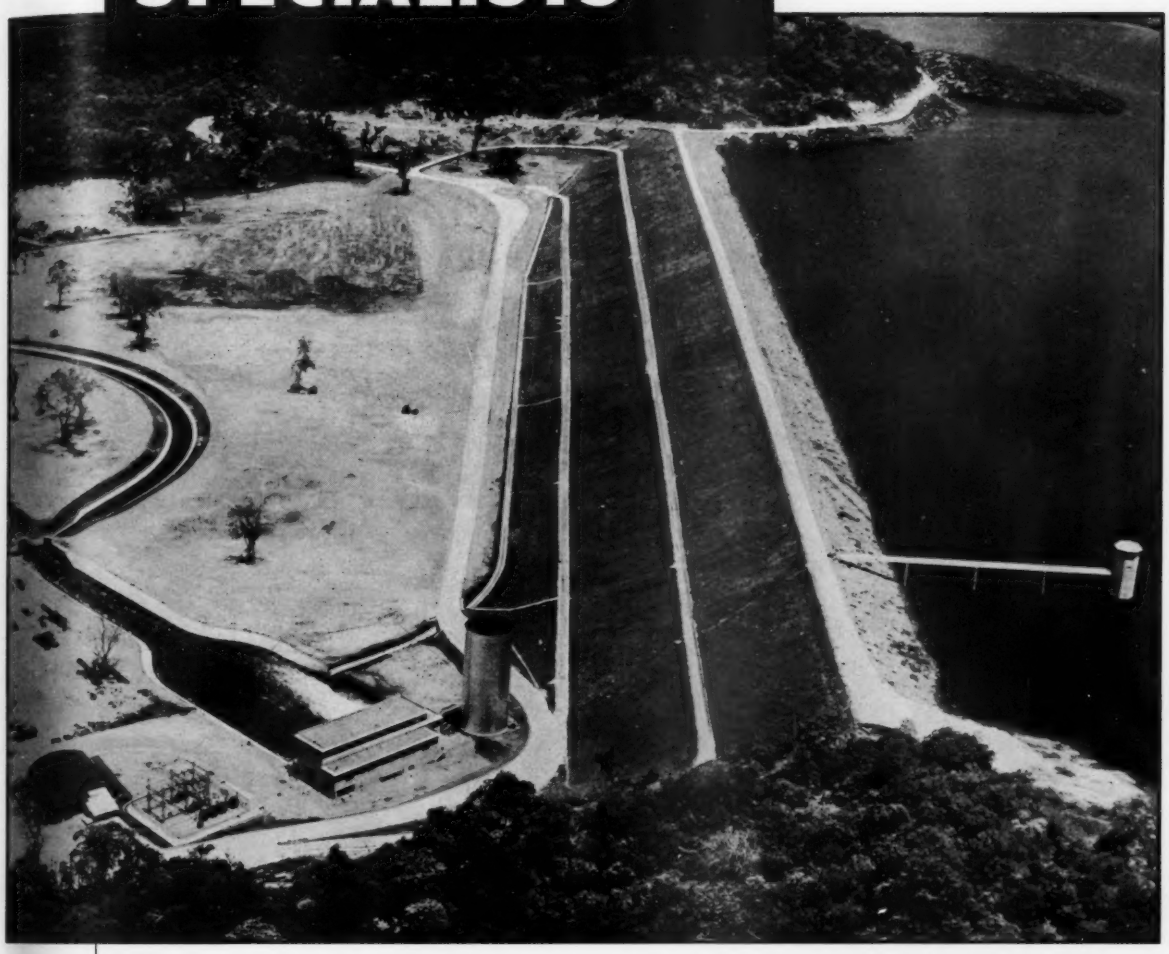

GAL OYA DAM, Ceylon — completed 1952 for hydroelectric power, flood control, irrigation. 3400 ft. long; 125 ft. high.

Harnessing water power has been a speciality of the Morrison-Knudsen organization for more than 40 years. The skill and experience accumulated over these years is your assurance of the efficient planning and competent execution so essential for the successful completion of large-scale water power developments.

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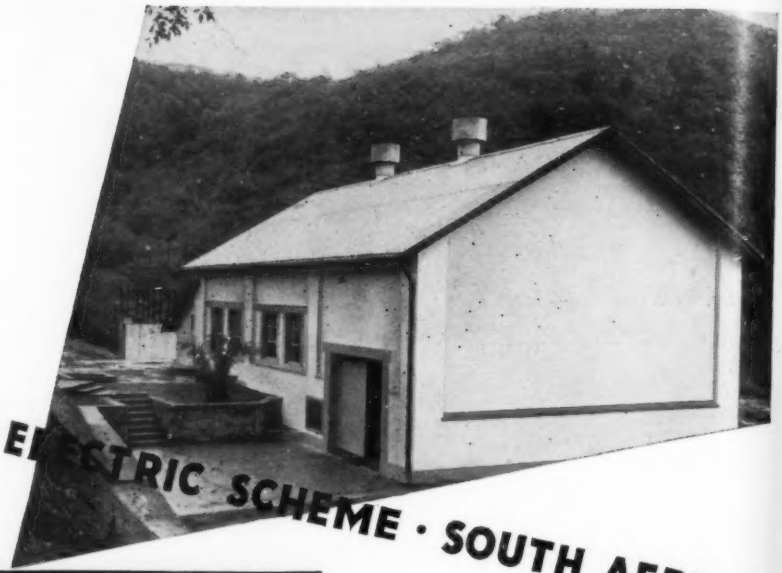

Exterior of power station

STANGER HYDRO-ELECTRIC SCHEME · SOUTH AFRICA

Interior, showing the two 725 B.H.P. GILKES Francis Turbines. Plant installed by Messrs. Stewarts and Lloyds of South Africa Ltd.

A number of South African municipalities have their own hydro-electric schemes supplying electricity for the town's lighting and power requirements. Those in the more isolated areas readily appreciate the many advantages of hydro-electric plant when compared with steam or diesel stations—no fuel cost, negligible maintenance, long life and absolute simplicity and reliability. The Stanger Municipal Hydro-Electric Scheme is typical of these installations and consists of two 725 B.H.P. 600 r.p.m. *GILKES* Francis Turbines operating on 100 ft. head and driving 500 kW. alternators.

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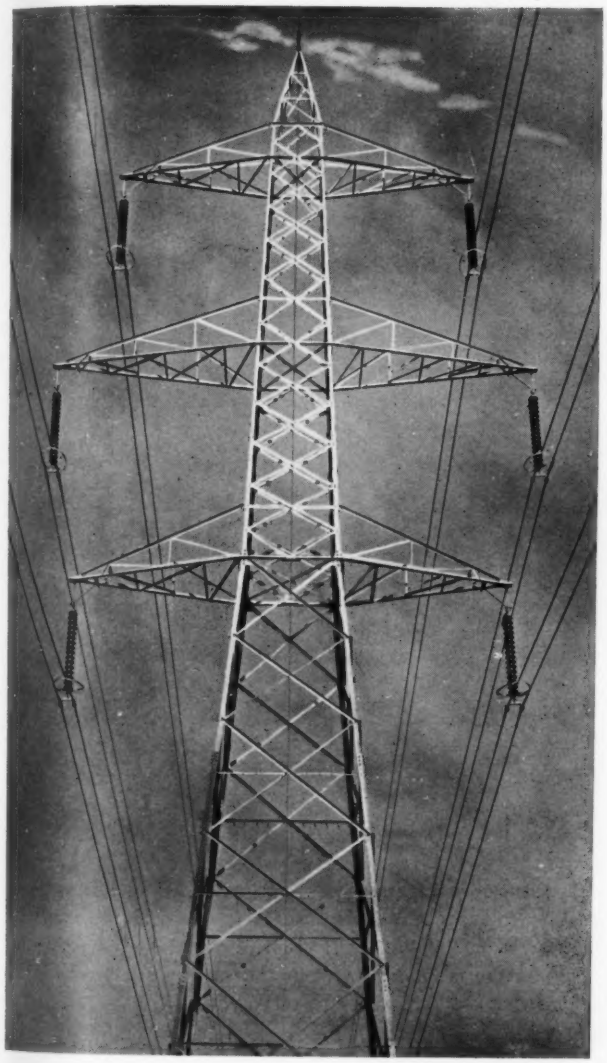
Erection equipment



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This 230 kV transmission line, built to feed the new Iron and Steel Works at Cornigliano in Italy, is designed to carry six twin 300 sq. mm. (.257 sq. ins. C.E.) S.C.A. conductors across very rough country with ice loadings up to 8 kg/m (5,4 lb/ft).

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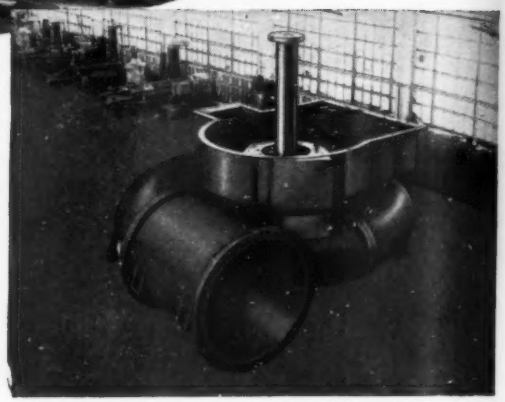

hydraulic turbines by **LEFFEL**

Anderson Ranch Dam, located on the Boise River in Idaho, U.S.A., is the highest earth-fill dam in the world. Two Leffel Turbines are installed in the Anderson Power Plant which provides power for the surrounding area. The turbines are of the cast steel spiral case, vertical Francis type and each is maximum rated at 28,250 HP, under 324 ft. net head, speed 277 RPM.

With a structural height of 456 feet, a base width of 2,650 feet and a crest length of 1,350 feet the Anderson Ranch Dam contains nearly 10,000,000 cubic yards of earth and rock. The reservoir behind the dam will hold 493,200 acre-feet of water.

When you consider turbines for *your* power project (whether it is a new installation or the expansion of an existing installation) we ask you to keep in mind the services which are offered by Leffel. Our 91 years of experience, our large modern plant, our thorough workmanship—all are ready to serve you.

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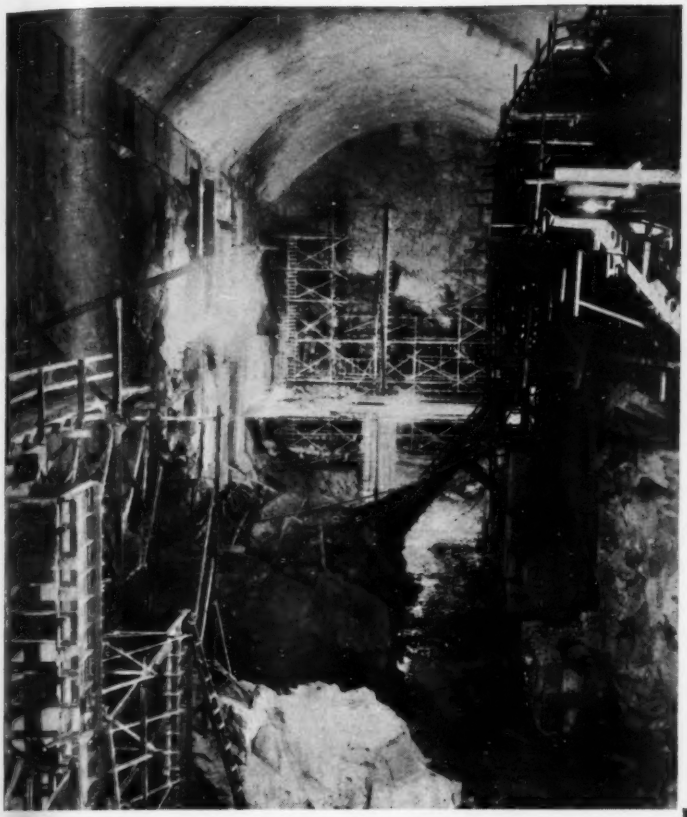

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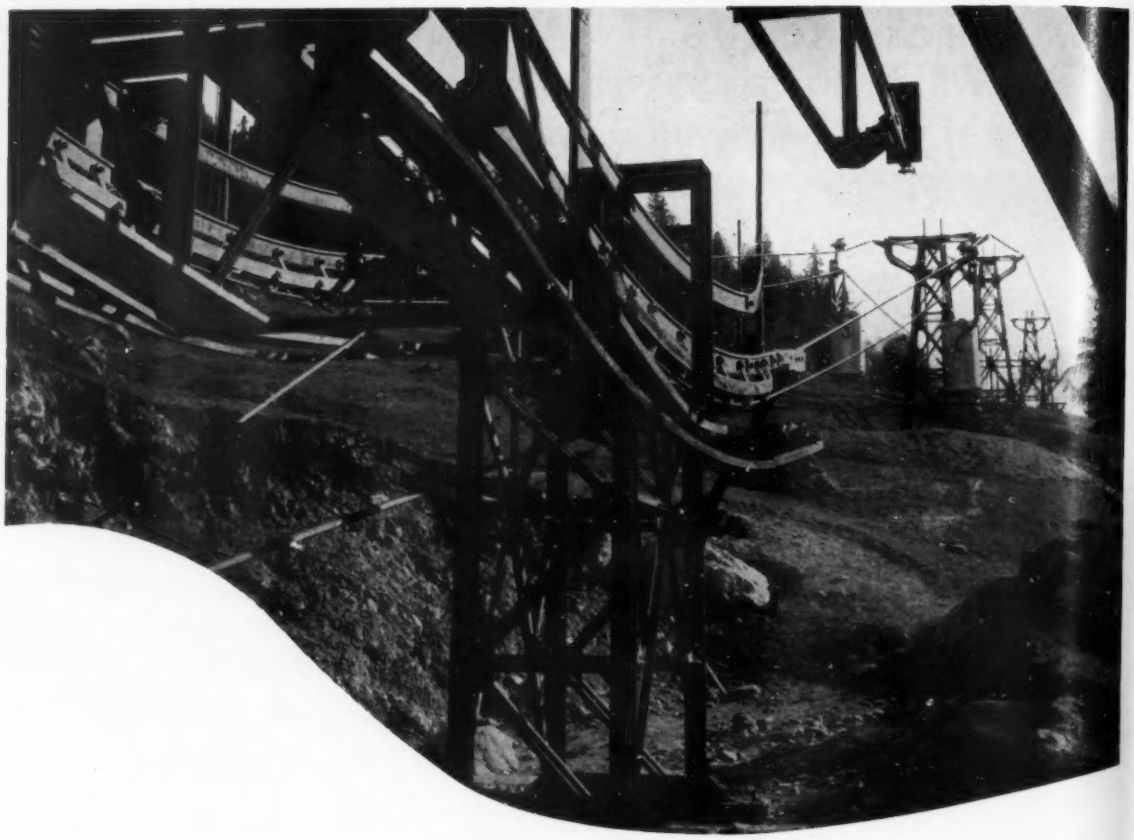

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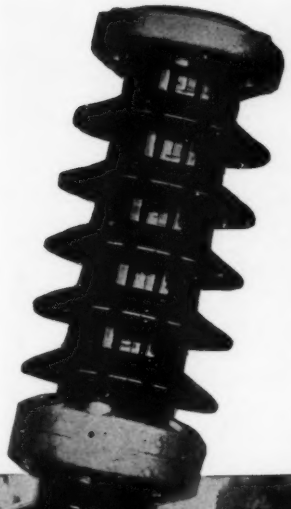
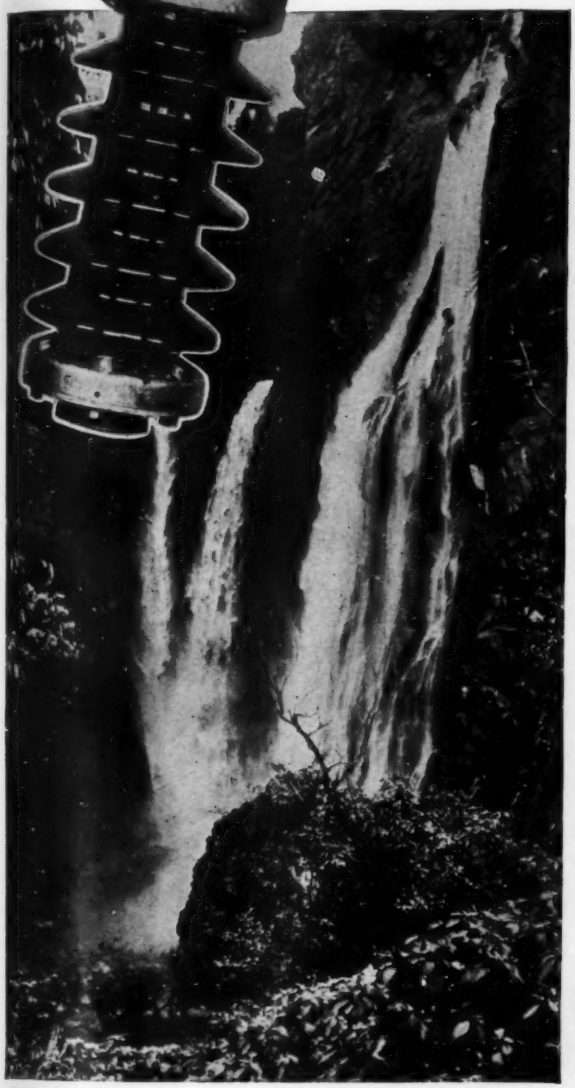
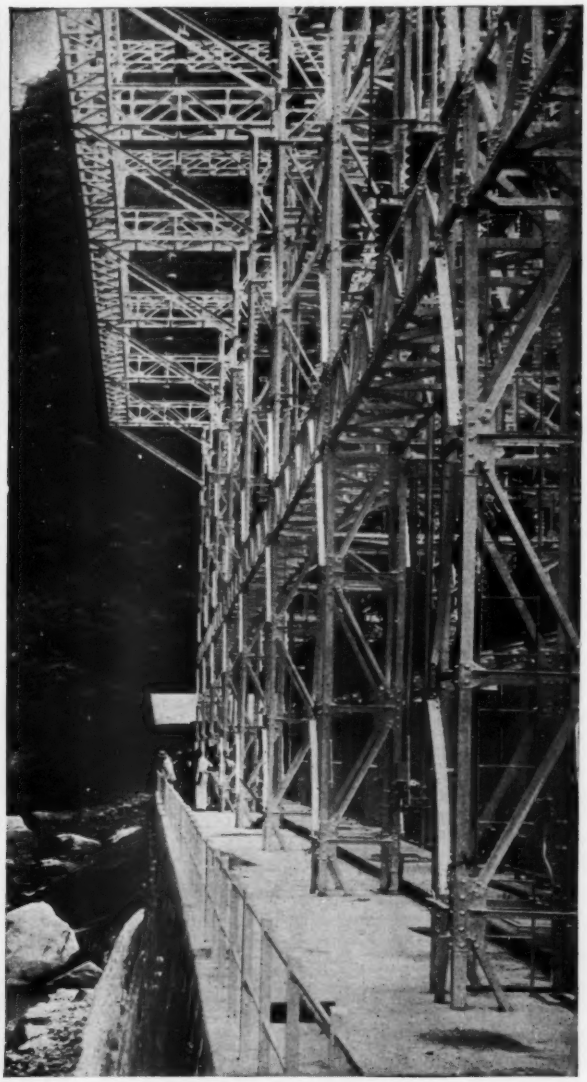


S.P.P. Post Insulators were specified for the 110kv outdoor switchgear on the Jog Falls Hydro-electric Scheme

The outdoor switchgear at Jog Falls Power Station, in Mysore State, India, equipped with S.P.P. Cylindrical Post Insulators type P.701.





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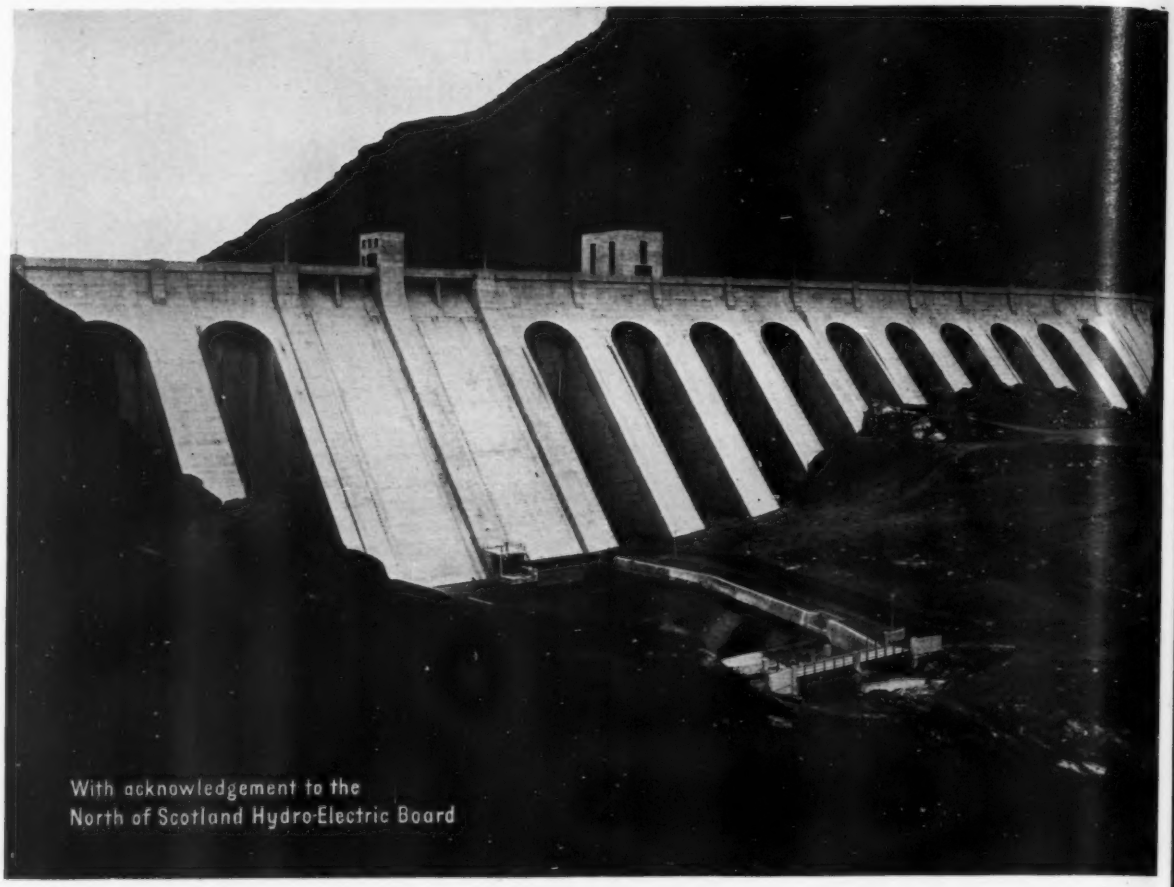

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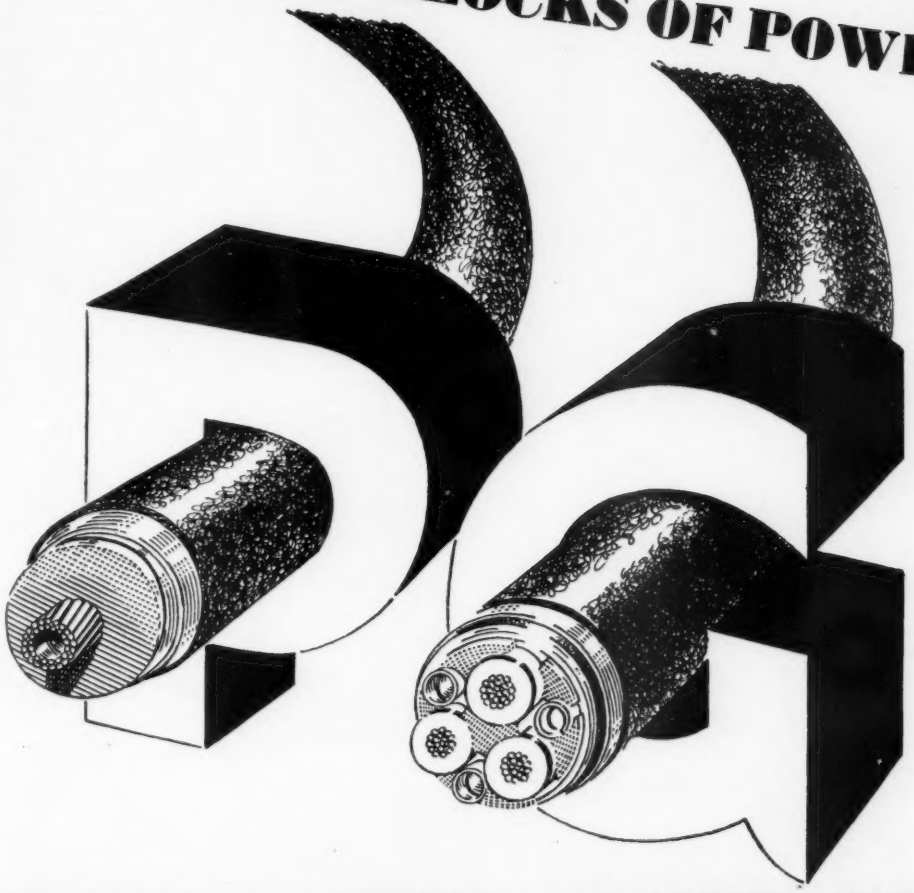

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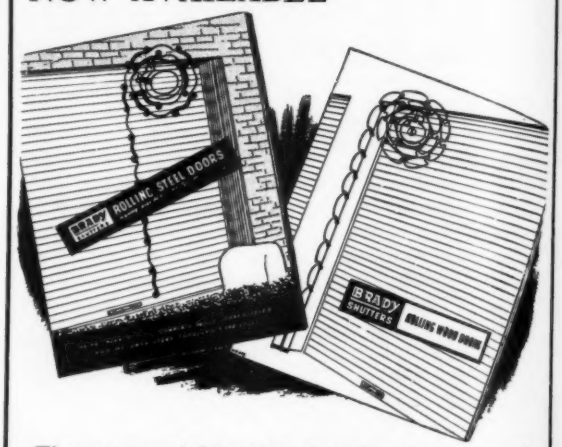

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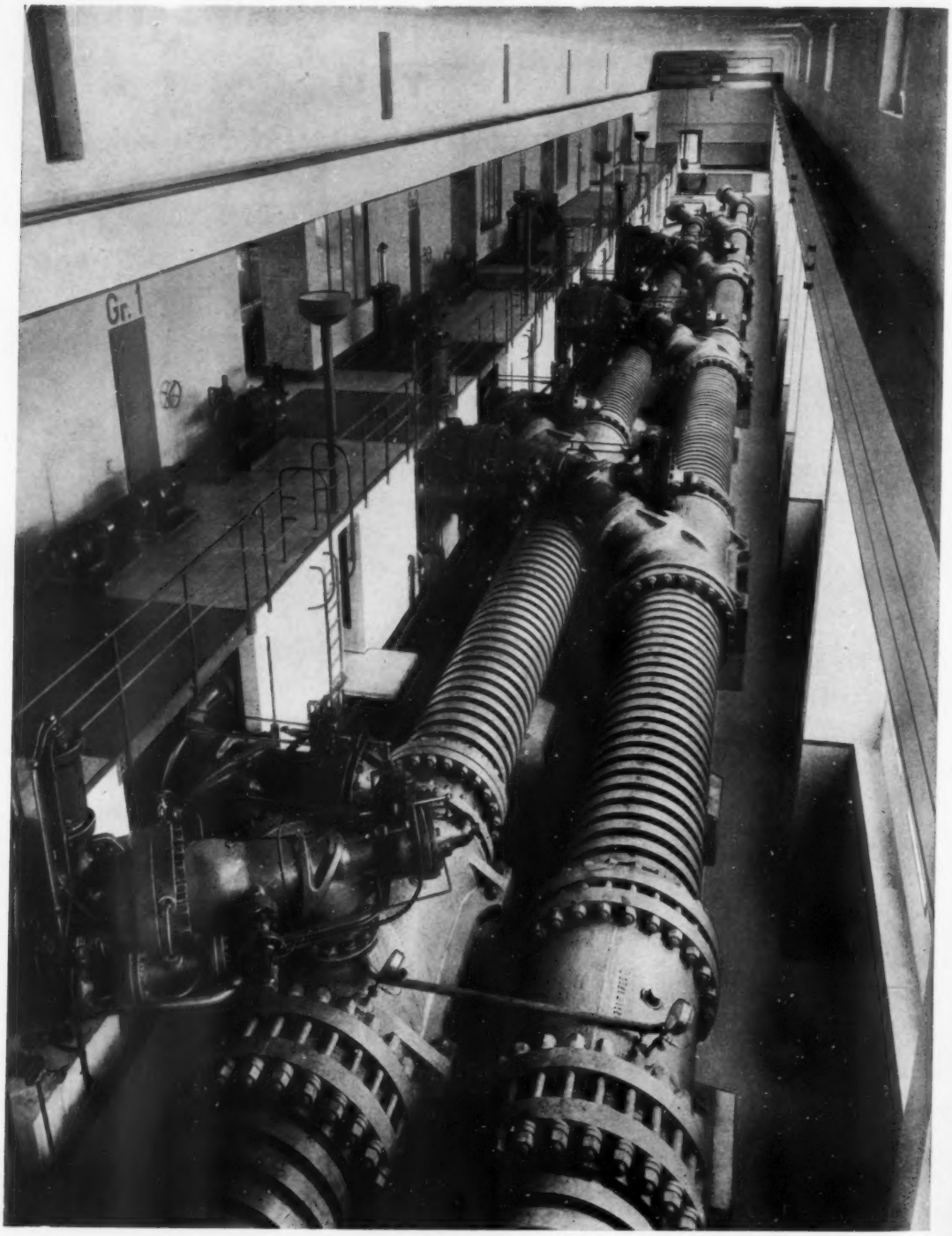

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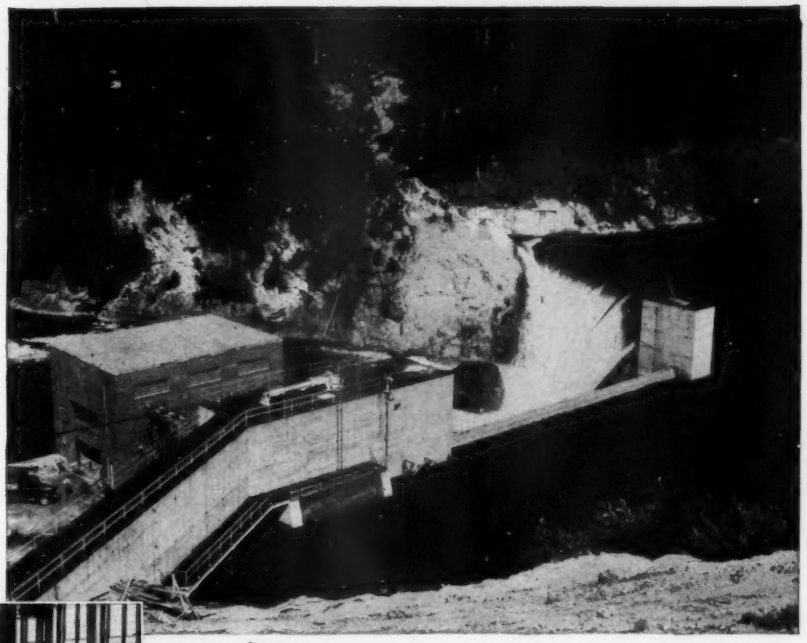

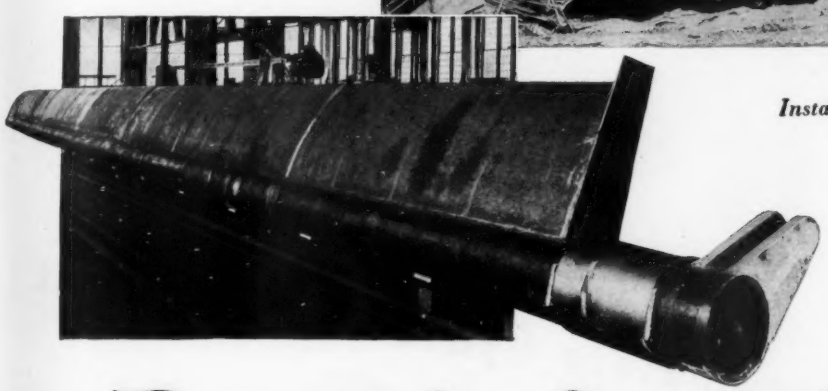

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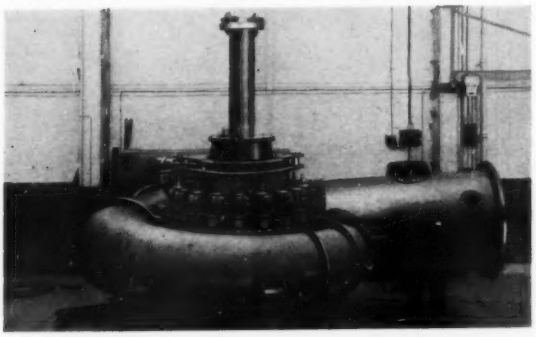

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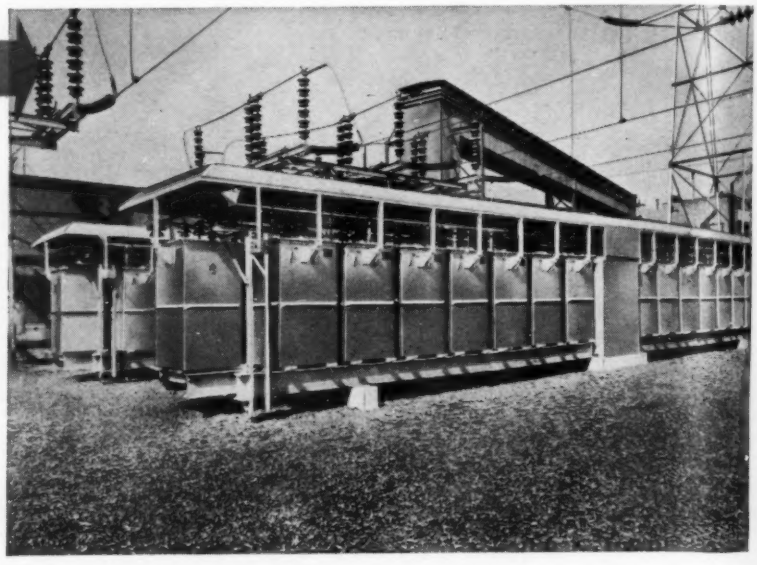

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Competition

ALTHOUGH there is ample reason for anxiety in the economic future, it is nevertheless true that the postwar unsettlement period is steadying into a state where competition—regarded in some quarters as ominous, and in others as healthy—is having roughly the same effect on the hydro-electric plant market as before the war. In the years to come the effect of keener competition on the design and manufacture of hydro-electric plant is likely to alter the views held by many in the past on the subject of standardisation. It has been widely thought in many European countries that very little standardisation could be applied to hydro-electric plant; and indeed manufacturers have prided themselves on the fact that each individual installation was tailor-made to the project concerned.

When severe competition faced the British electrical engineering industry during the economic depression period of the 1930's, the moves made were to intensify the trend towards the combination into one large organisation of firms making the various component parts, and secondly to seek greater standardisation to avoid wasteful duplication of ancillary items. During the postwar period, again taking a lesson from British experience, the need for increased productivity has led to even more standardisation concerning many electrical products. As an example, the case of distribution transformers may be cited. Faced with what amounted to a single customer in Great Britain—the Nationalised Electricity Supply Authority—and yet with a host of overseas customers, the manufacturers, the Supply Authority and representatives of consulting engineers concerned with overseas contracts, together with the appropriate Standards body, got together and evolved a range of standard specifications which after suitable discussion were eventually adjusted so that they suited practically all customers both at home and abroad. All manufacturers now work to these specifications, to mutual advantage between themselves and their customers. British manufacturers have also adopted electric motor sizes and specifications which enable their motors to conform to American standards. The International Electro-Technical Commission, meeting yearly, is slowly evolving specifications which are internationally acceptable for many items of electrical plant.

With these national and international moves in mind, it may well be the case that a far greater measure of standardisation will inevitably take place in regard to all items used in hydro-electric installations in the future. It may be that turbine designs will be evolved so that all the manufacturers of a particular country will in effect offer a standard range of designs which will fulfil the requirements of practically any project, even if turbines specifically designed for a particular scheme might perhaps produce a slightly higher efficiency. This may lead to a reconsideration of the sizes and numbers of units to be installed in a particular plant; and it may go even further, in the sense that where a particular river is to be harnessed at a number of points on its fall, these points may be chosen to fit in more with the application of standard plant units than with the other topographical features, or at least a compromise in this direction may well be effected.

In regard to high-pressure pipelines, valves and other similar components, measures of standardisation have already been hinted at in certain Continental quarters.

There is little danger that standardisation will bring with it stultification of design. In any case, fashions in hydro-electric machinery change slowly, and, for example, almost any one of the current designs of medium-head Francis turbine and its alternator would serve, unchanged, to meet the needs of a decade. After that, a new standard design would have another ten years of useful life before it need be modified.

In many countries, for example in France, there is a shortage of capital for hydro-electric development. With the conclusion of the large scale postwar Monet plan, *Electricitá de France* are finding it more difficult to get money for further developments, which are badly needed as the load continues to increase. This state of affairs will bring with it increased focus on first cost, and will mean that in those areas of the world where an enormous amount of development

still remains to be carried out, the country whose manufacturers can produce hydro-electric plant more cheaply than ever before, coupled with more rapid delivery, stands a good chance of obtaining orders in areas which up to the present time had been regarded as a "closed shop," to be exploited only by local manufacturing resources.

A Portuguese Inauguration

THE scheme for harnessing the Cávado and Rabagão rivers in northern Portugal has now reached a second stage by the inauguration of the Salamonde station on the Cávado. An arched dam 75 m. high impounds 55 million cu. m. of water, supplying an underground station in the left bank close to the dam at a gross head of 127 m. The tailrace tunnel is 1,860 m. long. Two 25 MVA 0·85 p.f. vertical Francis sets are installed, generating at 10 kV, the voltage being stepped up to 150 kV in a surface substation. The plant is expected to generate 200 million kWh in an average year.

Salamonde is the second of four installations planned for the development of the Cávado and Rabagão rivers. The Venda Nova 90 MVA scheme, on the Rabagão, was inaugurated in 1951 and was briefly described in our August 1951 issue. Two further installations, each of 60 MVA capacity, on the Cávado—the Caniçada downstream and the Paradela upstream of Salamonde—are due to come into service at the end of 1954 and early in 1956 respectively.

Finland's Water-Power Developments

ACCORDING to information published by the State-owned Imatra Power Company (Imatran Voima Oy., Helsinki), the total installed capacity of existing hydro-electric power plants amounts to 800,000 kW, giving an average output of 4,600 million kWh a year. Future constructional activity will be mainly in the north of the country as the greater part of water-power resources in the south is already in use. The Oulu, Kemi and Vuoksi projects, to produce an additional quantity of 1,160 million kWh a year on an installed capacity of 241,000 kW, are scheduled to be completed by the end of 1955. The total installed capacity of the country's hydro-electric plants will then be about 1,050,000 kW, their energy production —on a normal annual water level—will be about 5,750 million kWh per annum.

An Austrian Underground Station

WHAT is stated to be Austria's first underground power station, which will supply power for electrified railway lines, has been opened near Braz, in the Kloster Valley (Vorarlberg). The station was originally planned to be located on a surface site in the valley, but because of unexpected difficulties with foundations, and the danger from floods, falls of stone and avalanches, it was decided to install the generating sets and ancillary equipment in an underground chamber 25 m. below the floor of the valley. The chamber is 80 m. long, 22 m. wide and 17 m. high, and when fully equipped by next spring, it will house three generating sets to supply the railway requirements and one set for other purposes. Each set consists of two Pelton turbines with a maximum capacity of 10,000 h.p. and a 10,000 kVA generator.

Water is received from the nearby Spullersee hydro-electric plant and from the Alfenz stream, dammed at a height of over 1,000 m. A 25,000 cu. m. surge tank is located at the top of a 480 m. pressure tunnel leading to the power house, which will produce about 75,000,000 kWh per annum of power for the railways, saving 145,000 tons of imported coal.

Swedish Power Demand

DURING 1952 Swedish water-power plants produced about 20,000 million kWh. This means that the country has taken into use approximately one-third of all the hydraulic power that is technically and economically exploitable. Power demands, however, are rapidly increasing. The annual rise in consumption is at present 1,200 million kWh, but from 1957 and onwards it will probably be 1,500 million kWh per year. The new power plant at Stornorrfors outside Umeå in Norrland, which will have an annual output of 2,200 million kWh—some 200 million kWh more than the large Harsprånget plant above the Arctic Circle, inaugurated last year—will meet the increase in consumption for only 16 months when taken into use by the end of the 1950s. Yet it involves an investment of Kr. 200,000,000 (£13,800,000).

Investigations in Nigeria

THE Electricity Corporation of Nigeria was formed in 1950 to take over the organisation of the country's electricity supply from the Government, and the Corporation's Annual Report for 1951-52 gives an illuminating review of the position. Nigeria is in any case in the early stages of electrical development, but the outstanding problem is that of meeting a steadily rising demand with plant that has suffered severely during the war years, both in wear and tear and in lack of replacement and extension.

In addition to carrying out necessary short-term measures the Corporation is initiating, within limits imposed by shortage of staff, a review of the country's power resources. Important coal reserves exist, some of which have been mined on a moderate scale for a number of years, and drilling for oil is being carried out in regions where geological evidence suggests it may be found.

Of the hydro potential there is little factual information, but there is obviously a large reserve in Nigeria's two great rivers, the Niger and the Benue, and their tributaries. Preliminary investigations are already in progress on a number of the smaller and more accessible sites, including Ogun River, Osse Gorge, and Oni River in the west, Kwa Falls, Cross River, and the Metschum Valley in the east, and Shiroro Gorge, the Shere Hills, Gurara Falls, and Execution Falls in the north. Two major investigations are envisaged, one on the river-basin management on the Niger at Jebba, and the other on the co-ordinated development of the hydro resources of the Cameroon Highlands.

Owing to the almost complete absence of large-scale contour maps and hydrological data an immense amount of work will be entailed before any firm schemes can be formulated, but water power should

eventually make an important contribution to the country's needs. A small hydro-electric plant, of 1,500 kW capacity, is already under construction at Njoke in the Cameroons.

On the Oconee

THE Georgia Power Company is completing the final stages on the Plant Sinclair hydro-electric project at Furnam Shoals on the Oconee River near Milledgeville, U.S.A. Work was first started in 1929 but discontinued during the depression. It was built at a cost of 17 million dollars and will have two 22,500 kW units. The 105 ft. high dam is about 4,000 ft. long, and includes 1,224 ft. of concrete spillway and bulkhead.

Quebec Expansion

PREMIER DUPLESSIS has announced that nearly 300 million dollars is being spent on big hydro projects in the Province of Quebec. He stated that industrial progress in Quebec was so rapid that an additional 300,000 h.p. would be needed annually to keep pace with it. The latest project was the Eaton canyon development, which would serve the iron-ore mining area on the Quebec-Labrador boundary. Shawinigan Water and Power Company planned to develop another 100,000 h.p., but Mr. Duplessis did not indicate the location. When the Beauharnois project was completed it would develop 1,300,000 h.p., or twice the 1945 capacity. The project, undertaken by the Quebec Hydro Electric Commission, would commence next year, producing 300,000 h.p. from the Bersimis river (north shore of the St. Lawrence) with a potential 1,600,000 h.p. The Premier announced that on July 18 he would inaugurate the 100,000 h.p. development on the Manicouagan river. An additional 20,000 h.p. would also be developed at fall No. 2 along the Marguerite river to supply the Gulf Development Company's project which would cost 7 to 8 million dollars. Price Bros., at Kenogami, he added, would spend between 10 and 14 million dollars in developing 80,000 or 90,000 h.p., and the Aluminium Company of Canada had earmarked 125 million dollars for a Peribonka river project to develop 500,000 h.p. Mr. Duplessis pointed out that Quebec possesses the largest hydro-electric potential in Canada.

International Co-ordination in European River Development

SIXTEEN countries attending a recent session of the Electric Power Committee of the United Nations Economic Commission for Europe adopted unanimously a recommendation to overcome difficulties that might arise from the development and utilisation of rivers of interest to two or more countries. Under this recommendation "a State proposing to embark within its own territory on projects likely to have serious repercussions on the territory of other States, whether upstream or downstream, should first communicate to the States concerned such information as would enlighten them as to the nature of these repercussions." This communication would be calculated in particular to permit the opening of negotiations between the parties in the interests of the harmonious hydro-electric development of "successive" rivers in Europe.

The recommendation was proposed by an ECE group of legal experts who seek on behalf of the Committee to facilitate the conclusion of inter-State agreements concerning the development and use of successive rivers. It makes an important step towards the establishment of rules of international public law.

The recommendation, while addressed to European Governments, is also to be referred to the United Nations regional Economic Commissions for Latin America and for Asia and the Far East, because of its usefulness to under-developed countries.

Formation of "Yougelexport"

AN international body called "Yougelexport" has been formed under the aegis of the United Nations Economic Commission for Europe to handle economic, technical, financial and legal aspects of developing Yugoslav production of electricity for export to neighbouring countries. "Yougelexport" may develop into an important international hydro-electric power company. Its charter members are Yugoslavia, Austria, Italy and Western Germany. Belgium, France and Switzerland are also seriously interested in the work. A recent study by the Secretariat of the United Nations Economic Commission for Europe reported that only 2 to 3 per cent. of economically exploitable hydro-electric resources in Yugoslavia have been harnessed. The resources of the other countries in "Yougelexport" are already exploited to a much higher degree.

Negotiations are in progress between Austria and Yugoslavia concerning the hydro-electric development of the river Drave, which flows through those two countries. Progress had been made in reaching agreement on present and future rules for exploiting hydro-electric installations on the river, and it is hoped that a protocol between the two countries can be signed in Geneva in October.

Guatemala Project

A DETAILED survey for a hydro-electric project on the Pacific coast near Esquintla is in progress for the Ministry of Public Works, Guatemala, and will take six months. The scheme is expected to be in operation in four years, and tenders for construction and equipment are to be invited from foreign contractors and manufacturers.

Jordan Scheme Ratified

THE scheme for harnessing the Yarmouk River, referred to in a note in our August 1952 issue, has been ratified by the Jordan and Syrian Governments. This river forms part of the frontier between Jordan and Syria, and the objects of the scheme are to provide intensive irrigation for 160,000 acres, to settle a large number of Arab refugees, and to give employment to refugees during the constructional period. A power station will be built at Addasiya and a second station near the Dead Sea.

The work is expected to take three years to complete and to cost £18 million, part of which will be borne by the United Nations Relief and Works Agency. Jordan is to contribute £150,000.

Book Reviews

The Design of Valves and Fittings. By G. H. Pearson, A.M.I.Mech.E., A.M.Inst.F., A.I.Mar.E. Sir Isaac Pitman & Sons Limited, Parker Street, Kingsway, London, W.C.2. 430 pp. 230 ff. Price 50s. net.

This book is concerned primarily with steam and other industrial valves, and as such does not impinge to any large extent on the domain of the hydro-electric specialist. Indeed, it makes no attempt to deal with the types or sizes of valves and sluices in which our readers will be mainly interested. Nevertheless there are two most useful chapters on hydraulic valves—one on hydraulic stop-valves and the other on wedge-gate sluice valves.

Within its prescribed field the book is excellent, for the technical design of valves seems to have received scant attention in the press and in textbooks, and Mr. Pearson's book handles the subject with commendable thoroughness. We are also intrigued to see photographs of an early Roman bronze stopcock salvaged in 1929 from Emperor Caligula's first galley; these photographs were supplied by Dr. Ucelli of Riva Costruzioni Meccaniche, who is President of Museo Nationale della Scienza e della Technica, Milan.

In saying that Mr. Pearson has not covered the hydro-electric field we are offering no criticism whatever of his book; we are merely warning our readers that it is not the relevant source of information on the main hydraulic control equipment of a water-power scheme, although it deals usefully with the design of the various auxiliary valves to be found in any hydraulic station.

B.I.M.C.A.M. Handbook, 1953. The British Industrial Measuring & Control Apparatus Manufacturers' Association, 21, Tothill Street, London, S.W.1. 144 pp.

This Association, which was inaugurated in 1944, includes 27 of the leading British manufacturers of industrial instruments, meters and control apparatus. Their handbook, which is the first to be issued, is a well-produced and illustrated bound volume which traces the growth of the British instrument industry, outlines the importance of instrumentation, and explains the constitution and objectives of the Association.

Wehr- und Stauanlagen (Weirs and Barrages). Göschen Collection No. 965. By Ing. Hans Dehnert. Published by Walter de Gruyter & Co., Berlin W. 35. 6 in. by 4 in., 134 pp., 90 ff. Price in Germany, paper bound, DM. 2.40.

This book deals on the whole with all hydraulic works other than large valley-closing dams. While the meaning of " Stauanlage " is perfectly clear, the term " Wehr " covers in German a number of structures varying from weirs proper to sills and spillways, and including all types of sluices; all these terms are adequately defined in the first chapter of the work (§ 1 to 3). The viewpoints which govern the designing of these installations are discussed in chapter II (§ 4: Location and height of structures; § 5: Design, materials and mode of operation). Chapter III is devoted to the technical calculation of the various types of weirs and overflows; the design, construction and working of stationary spillways are reviewed in chapter IV, and mobile barrages and the various patterns of sluice gates in chapter V. Foundation piers, embankment structures and protection against scouring are dealt with in chapter VI, and ancillary works (intakes, bottom outlets, locks, navigation, log and fish passes) are discussed in chapter VII, which is followed by a comprehensive index.

This booklet, in every respect up to the tradition of the Göschen Collection, should prove, in its sphere, as valuable as Professor Tölke's little work on large dams, reviewed in our issue of last June.

Fachwörterbuch für das Bauwesen (Technical Dictionary for the Building Trade, German-English and English-German), compiled by Paul W. Liebe, published by Franckh'sche Verlagshandlung, W. Keller & Co., 5-7 Pfizerstrasse, Stuttgart-0. 5 in. by 6½ in., 215 pp. Price in Germany, cloth bound, DM.10.00.

This pocket-size dictionary contains no less than 12,000 technical terms, and though obviously intended for the general builder, should prove very useful to the civil engineer and contractor especially interested in the construction of dams and other hydraulic works. There is a number of more or less obsolete English terms, but as these hardly appear nowadays in technical works and journals, this should not seriously impair the practical value of the work. Print, paper and binding are very good.

Il Piave e la sua utilizzione (The Piave river and its development). A house publication of the Società Adriatica di Elettricità, Venezia, printed by Officine Grafiche Carlo Ferrari, Venice, 1952, 8½ in. by 12 in., 118 pp., 41 ff., 7 plates.

With the construction of the Piave-Boite-Vajont project, comprising the Soverzene power station, the Società Adriatica di Elettricità completed a new and important stage in the Piave hydro-electric development which had started with the setting up of the Piave-S. Croce, Cordevole and Piave-Ansiei plants.

The publication under review begins with a geological sketch of the Piave basin by Professor G. dal Piaz, followed by a historical and hydrological survey of the river by Ing. Luigi Vollo. The hydro-electric development of the river is then reviewed in detail, and the volume concludes with a full description of the Soverzene power station.

The book is handsomely bound in cloth, richly printed on art paper, and the illustrations, photographic and line, are of the highest order. The plates, particularly the geological and hydrographical maps of the Piave basin, and the general schematic profile of the plants, deserve special mention.

The Società Adriatica di Elettricità must be given every credit for a publication which is indeed a worthy commemoration of a remarkable achievement.

NOTE. The Soverzene power station was the subject of an article by Dr. Ing. Mario Mainardis in the March and April issues, 1952, of WATER POWER, pp. 95 and 152.

British Standards Institution Moves. The British Standards Institution is in full operation at its new premises at No. 2 Park Street, W.1 (Telephone No. MAYfair 9000). As already announced, the new building will contribute to more efficient working by concentrating the B.S.I.'s scattered departments under one roof. It will also provide increased and more convenient accommodation for the 13,000 specialists who attend the 3,500 B.S.I. Committee meetings held during the course of each year.

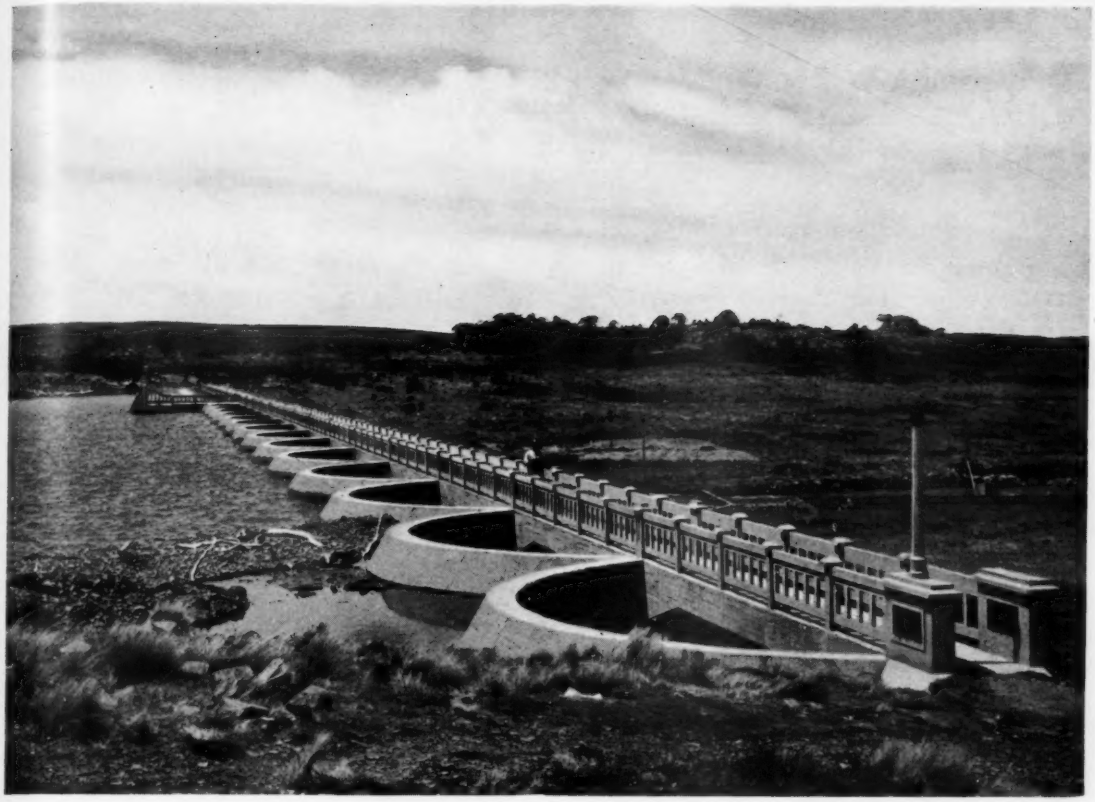

Fig. 1. A view of the Miena dam at the southern end of the Great Lake

Hydro-Electric Power in Tasmania

Tasmanian hydro-electric capacity should be virtually doubled by 1955 and trebled by 1960. This article, which has been specially written for this journal by the Hydro-Electric Commission of Tasmania, outlines the history of development, and gives particulars of present construction and future plans.

WITH some minor exceptions the right to use the waters of the State of Tasmania is vested in the Hydro-Electric Commission, by the Hydro-Electric Commission Act of 1944, which authorises the Commission to develop and reticulate electric power for all purposes.

The Hydro-Electric Commission conducts a continuous survey of the water-power resources of the State assisted by modern methods such as aerial photography and geophysical exploration. Although the survey is not yet conclusive, it is considered that at least 2,500,000 h.p. of continuous power can be economically developed. So far 293,200 h.p. of generating plant is in commission, while present construction is planned to bring this total to 542,200 h.p. by 1955. Further construction which has been approved by the Parliament of Tasmania and is about to be commenced will increase this to 759,200 h.p. There will remain, however, very considerable resources for future development.

Most of the water potential is located on the Central Plateau. This has an area of about 1,500 sq. miles at an altitude between 2,000 and 4,000 ft., and is subject to a heavy rainfall—from 80 in. per annum on the western perimeter to 30 in. in the east. On the plateau are a number of large lakes, which provide the means for storing water at low cost. These include the Great Lake, with an area of 58 sq. miles, Lake St. Clair and Lake Echo, each over 12 sq. miles, and others of smaller area. The plateau is practically uninhabited and regulation of rivers and lakes and changes of water levels necessitate very little or no compensation expenses.

The Derwent River and its tributaries, which flow south easterly, carry off by far the greater part of the water which falls on the plateau, and these rivers are

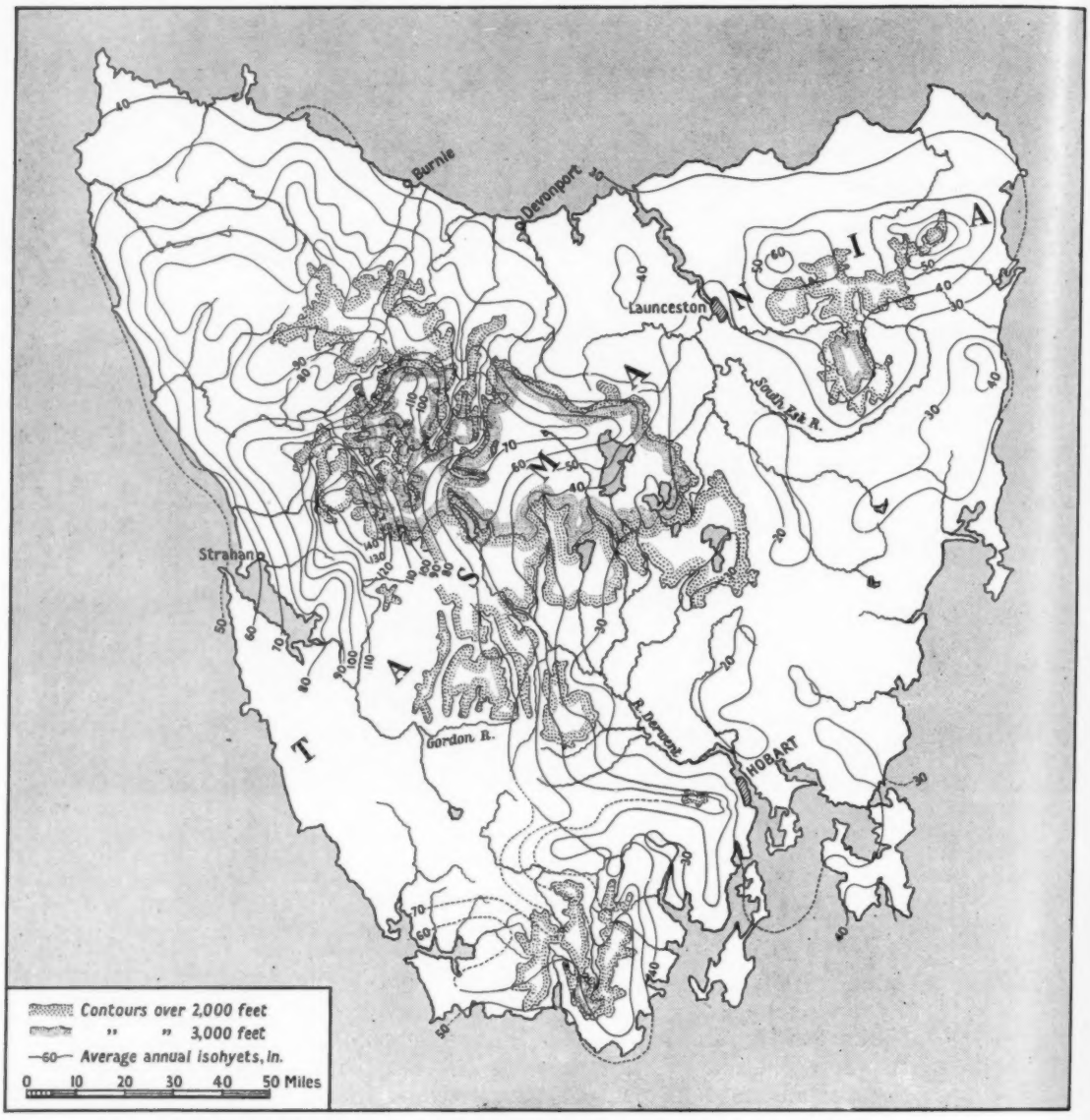

Fig. 2. Contour map of Tasmania showing average annual isohyets

therefore the most abundant source of power. They have been the cheapest to develop to date and most of the existing generating stations are located on them.

The three main rivers which run to the west from the plateau—the Arthur, Pieman and Gordon—have only a small portion of their catchment areas at high levels, but on their way to the coast they run through regions of even higher rainfall, and their power potentials are therefore considerable. However, development may be rather more expensive due to inaccessibility and climate, and has been deferred in favour of other more convenient schemes.

A number of rivers which drain from the plateau towards the north and north-west coast, including the Emu, Forth and Mersey, have small catchment areas at high levels, and no natural storage. On each river there are good sites for dams, but little scope for storage.

There are two other important water-power sources, the Esk River in the north, and the Huon River in the south, which are independent of the Central Plateau. The Huon has a large low-level catchment in the high rainfall area towards the west coast. Because the power station would be so near Hobart—the State capital and a heavy consuming area—and storage could be provided at reasonable cost, it has considerable value as a future peak-load power station. A great proportion of the South Esk catchment receives rain from north-easterly winds, and to some extent development will spread the risk in the event of low rainfall on the central plateau which is subject to prevailing westerly weather. A power station now under construction at Trevallyn, near the City of

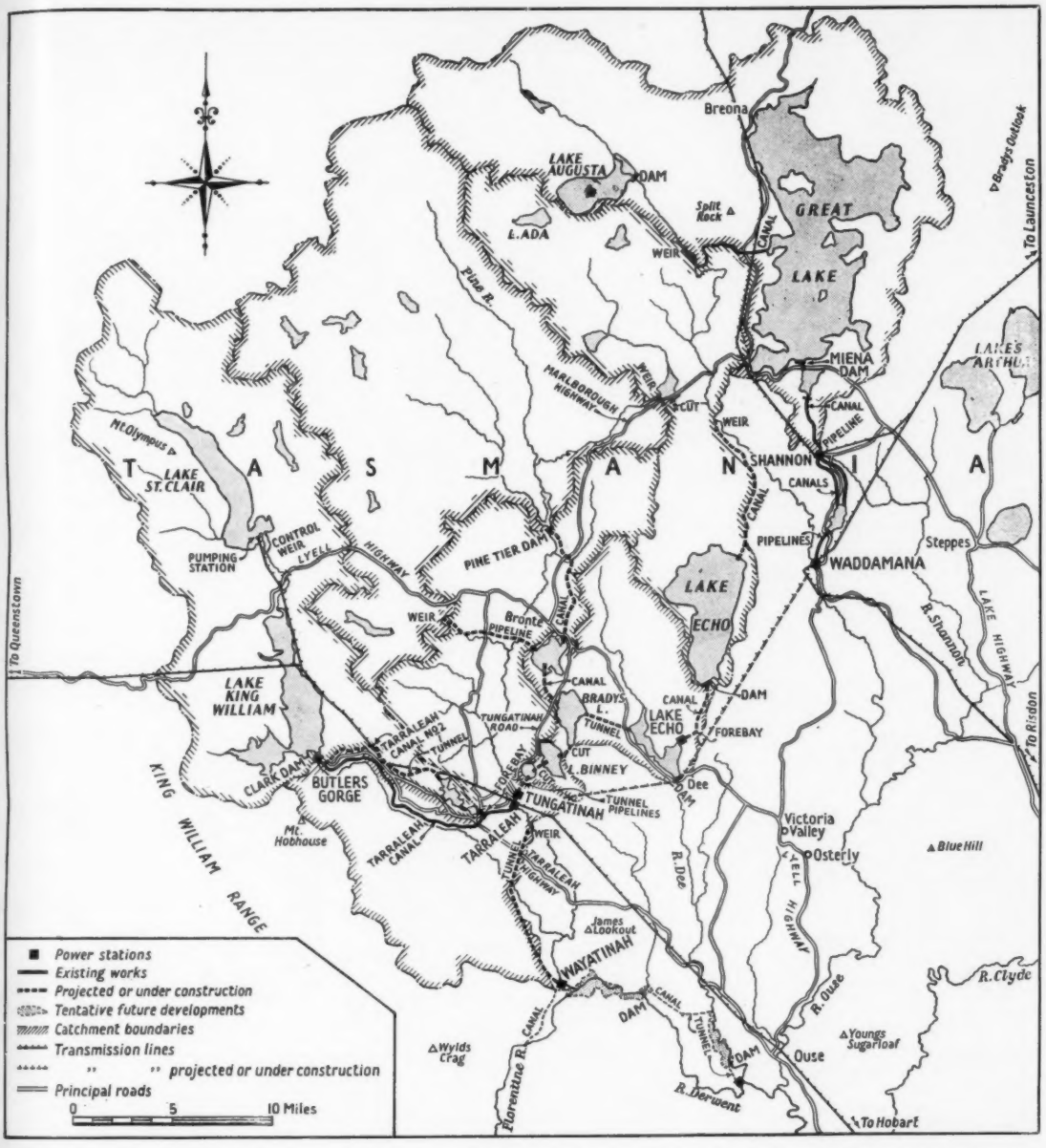

Fig. 3. Map of the River Derwent development including the proposed Lake Echo and Wayatinah schemes

Launceston, will be supplied with water from this river and is described later.

A considerable part of the catchment in Tasmania is at high level, with substantial natural storage available, and this has made it possible to produce energy at lower cost than elsewhere in Australia, or in most other countries. Other contributing factors to the low costs are that rainfall is distributed fairly evenly throughout the year, with comparatively small yearly variations. The cheap power has caused several large electro-chemical works with high load factor to become established in Tasmania; as a consequence the system load factor is also very high and at present is 65 per cent.

EXISTING WORKS

Duck Reach

The first hydro-electric power station in Tasmania was the Duck Reach station, of 600 h.p., which was erected on the South Esk River by the Launceston City Council in 1895. It is located only 5 miles from the city and operates under a head of 110 ft. This power station was enlarged to 1,600 h.p. in 1905, and to 2,600 h.p. in 1919, and finally vested in the Hydro-Electric Commission in 1944. It will be abandoned following completion of the Trevallyn power development, now under construction, which is being built primarily to meet the needs of the Australian Aluminium Commission's works at Bell Bay.

Waddamana "A"

In 1911 the Hydro-Electric Power and Metallurgical Company built a small dam at the Great Lake, and by construction of canals and pipelines conveyed the water to Waddamana, where it was intended to generate 10,000 h.p. to supply the Company's requirements for the electrolytic treatment of complex ores. For various reasons the plans did not come to fruition and in 1914 the assets were taken over by the Tasmanian Government and placed under the direction of a Hydro-Electric Department formed for the purpose. By May, 1916, two 5,000 h.p. turbo-alternators had been put into commission at Waddamana, and electricity was transmitted to Hobart and surrounding districts.

Further construction works were commenced in 1919 to increase the capacity of Waddamana to 66,000 h.p., and in order to provide the necessary storage a multiple-arch dam was built at Miena, the outlet from the Great Lake. The extension was completed during 1922.

A canal, 5 miles long, to divert the waters of the Ouse River to the Great Lake, was completed in 1923. This has been periodically increased to its present capacity of 650 cusecs.

Better regulation of the catchment above this canal (107 sq. miles) will shortly be gained by the construction of a small but unique rock-fill dam. At an altitude of 3,775 ft. the country is barren and stony. The dam is primarily of rock fill with a sealing face of clay stabilised between transition zones with rock fill.

Shannon

After the creation of the Hydro-Electric Commission in 1930, it was decided to utilise the controlled flow of water from the Great Lake and the fall in level existing between there and the Waddamana forebay lagoon. An earthen dam was built to divert the water from the Shannon River, first into a canal, and then by two pipelines to the Shannon power station 258 ft. below, whereby 14,500 h.p. was added to the system in 1934. The water, after passing through Shannon power station, discharges into the Waddamana canal, to be used again at Waddamana power station.

Tarraleah

It soon became necessary to consider a larger scheme, and in 1933 it was decided to utilise the run-off of a catchment to the west of the Great Lake nearer the regions of heavy rainfall. The site selected for the power station was on the Nive River, some six miles above its confluence with the Derwent River and became known as Tarraleah.

Construction was started in 1934, and the initial installation of three 21,000 h.p. Pelton-wheel turbines operating under a head of 980 ft. was placed in service in February, 1938.

The scheme involved the construction of a weir across the River Derwent at the outlet from Lake St. Clair to control flow of water from the lake. By this means the level of the lake is raised 5 ft. A pumping station with four 150 cusec pumps has also been installed to utilise 19 ft. of storage below normal level. The total controlled storage at Lake St. Clair is 240 sq. mile feet.

The flow follows the Derwent River to Butlers Gorge, where it is diverted by a 900 cusec canal 14 miles long to Tarraleah power station. To secure increased storage near the power station, a percentage of the normal canal flow is pumped against a 20 ft. head into an adjacent lagoon during off-peak periods. This and other works have made it economical to increase the turbine capacity of the Tarraleah station to 126,000 h.p.

Waddamana "B"

Before the outbreak of the last war it was decided that in order to make better use of the Great Lake storage it would be necessary to increase the capacity of the Waddamana station, and to duplicate the Waddamana canal. Although the war impeded progress, two units of 16,700 h.p. had been installed by its termination, and a third unit was put into commission during 1946. The power station was brought to its ultimate development by the installation of a fourth unit in 1949, which brought the total capacity to 66,800 h.p. at Waddamana "B." The duplicate canal

Fig. 4. Looking down the penstocks on to Waddamana station

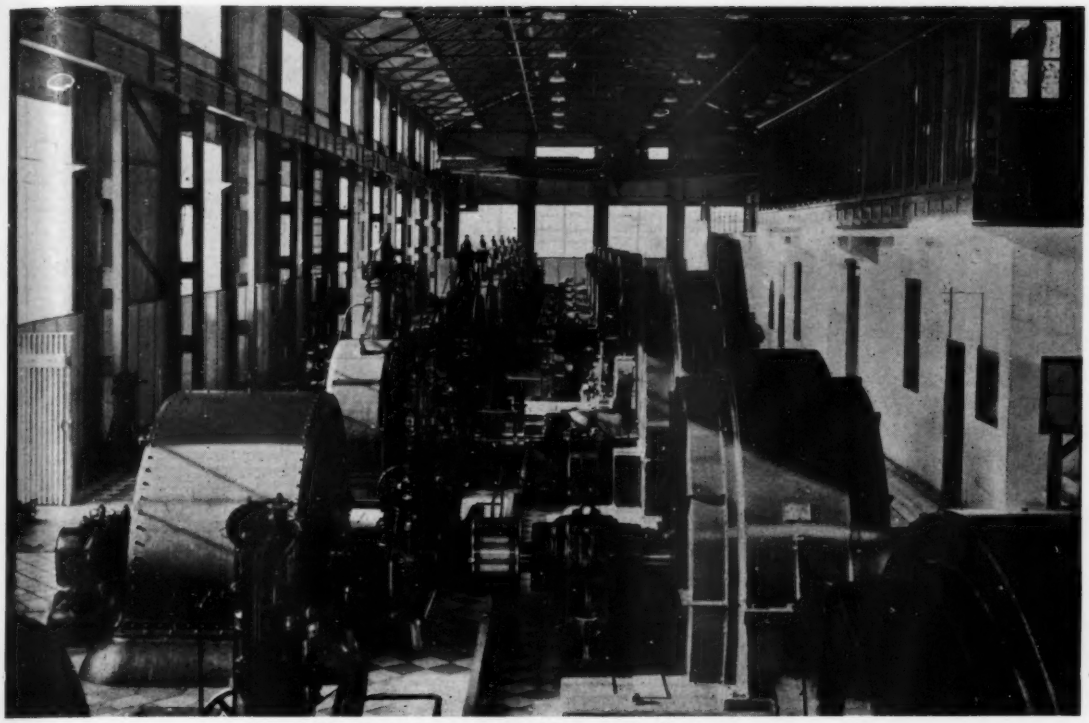

Fig. 5. Interior of Waddamana "A" station

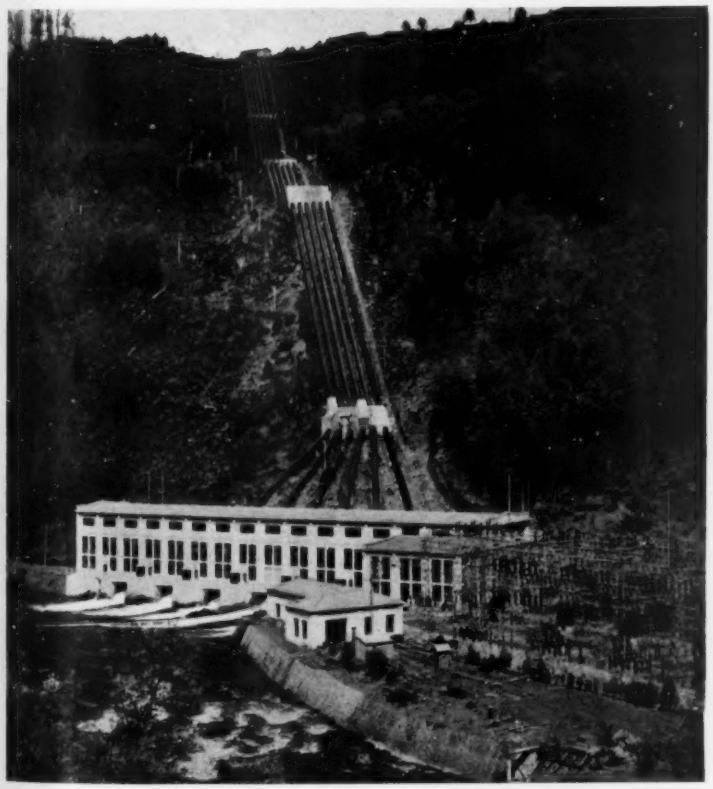

Fig. 6. General view of Tarraleah power station

of 650 cusec capacity, was completed during 1947-48.

Clark Dam and Butlers Gorge Power Station

Work on the Clark dam started in 1939, and is now virtually completed. The dam, which is the largest single-arch concrete dam in the Southern Hemisphere, is 200 ft. high with a spillway featuring a ski-jump designed to dissipate the energy of a flood of 20,000 cusecs. Top water level is 2,342 ft. above sea level. The reservoir provides 380 sq. mile feet of storage. This, with Lake St. Clair, was designed to ensure a continuous outflow of 900 cusecs through the driest period on record.

The power station at the foot of the dam was put into commission in September 1951. The single turbine operates under whatever head is available between 81 and 161 ft., and the maximum rated output is 17,100 h.p.

To increase the security of the system and to permit variable seasonal loading of Tarraleah, a second canal of 300 cusec capacity will be constructed from the Clark dam to Tarraleah. Work on this is as yet in a preliminary stage.

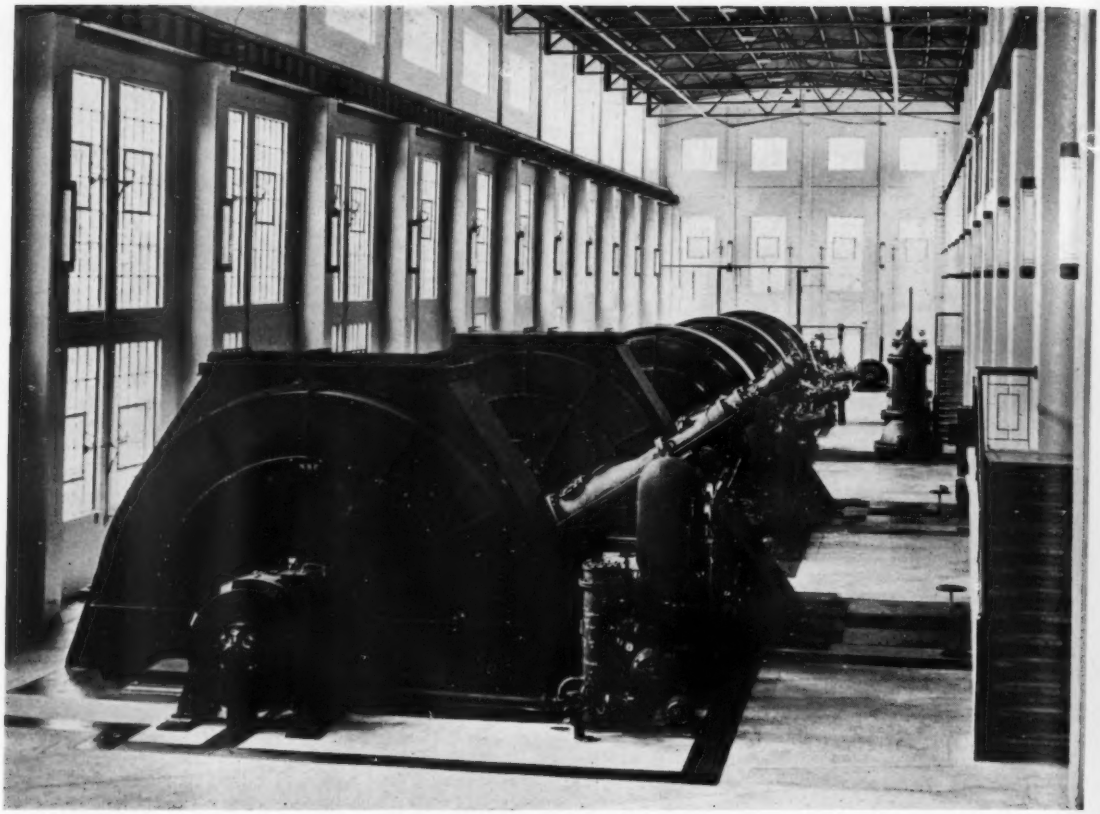

Fig. 7. Interior of Tarraleah power station

PRESENT CONSTRUCTION

The Hydro-Electric Commission is at present engaged upon the most progressive construction programme in its history, and it is expected that the present generating capacity will be almost doubled in 1955, and nearly trebled by 1960. Further developmental work is being planned and economics of construction investigated.

Trevallyn Power Development

The Trevallyn power development is being undertaken primarily to meet the power requirements of the aluminium industry. It involves the construction of a power station at sea level—though 30 miles from the sea—together with civil-engineering works to divert water from the Second Basin in the South Esk River to a power station on the River Tamar, about two miles from the City of Launceston. To provide some storage for this scheme, weirs will be constructed at the outlets from Arthur and Woods Lakes, of the Lake River, a tributary of the South Esk.

At the outlet from the Second Basin a 75 ft. high concrete dam will be constructed. This has been designed to pass a flood of 300,000 cusecs and will normally create a lake three miles long, giving 65,000 cusec-hours of pondage. To conduct the water to the power station, a two mile long tunnel, 21 ft. 6 in. in diameter, is being driven under the intervening ridge. The intake structure will house two roller gates in series for dewatering the system. At its lower end the tunnel will successively branch into four penstocks, each 6 ft. 9 in. in diameter, to lead the water to the four reaction turbines, each of 28,000 h.p., operating under an effective head of 360 ft. The water will finally discharge from the power station into the Tamar River, at sea level.

The Tungatinah Power Development

The extensive plateau area between the Great Lake and Lake St. Clair drains into two main catchment areas—the Nive River and the Lake Echo-Dee River catchments, with an average combined run-off of about 800 cusecs. The Tungatinah power development will regulate most of these waters, and following its completion practically the whole run-off from the Central Plateau will have been brought under control.

First Stage of Construction. A concrete gravity overflow dam is being constructed across the Nive River about 2½ miles upstream from the Lyell highway. This will divert the Nive River water via flume, siphon and canal of 1,650 cusec capacity to a plateau, which extends at an elevation of about 2,200 ft. along the eastern bank of the River Nive.

Earth and rock-fill dams built across the outlets from Woodward's, Brady's, Big and Nive marshes, will form a chain of lakes which, together with canals and open cuts, will carry the river flow with small loss of head. The new lakes so formed will be stocked with fish and have been renamed Bronte Lagoon,

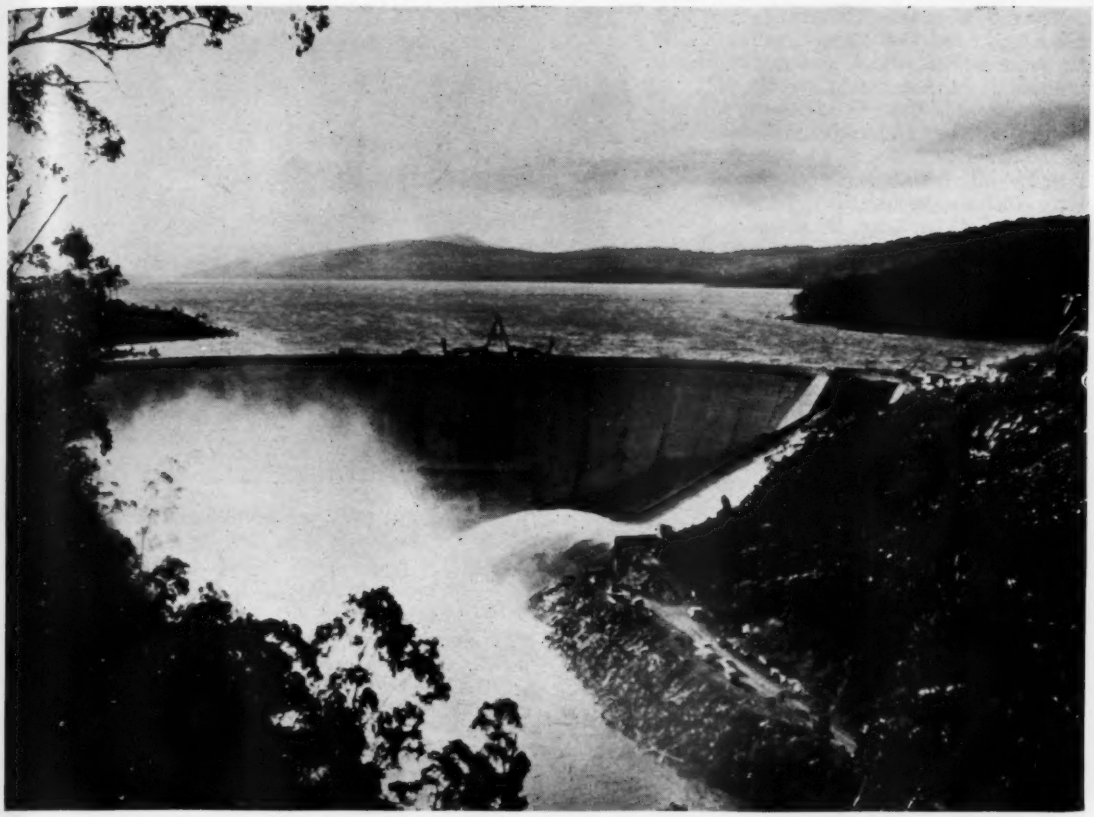

Fig. 8. View of Clark dam with the spillway discharging at 20,000 cusecs

Brady's Lake, Lake Binney and Tungatinah Lagoon respectively. From Tungatinah Lagoon a tunnel and then five steel pipes will carry the water to Tungatinah power station, located on the Nive River almost opposite the existing Tarraleah power station. The static head on the Francis turbines in the Tungatinah power station will be 1,005 ft.

The run-off from the smaller Clarence River catchment will be carried to the newly formed Bronte Lagoon by means of a pipeline, 5 ft. 3 in. in diameter and 29,500 ft. long. The crossing of the Nive River will be with a self-supporting steel pipe of about 120 ft. span, and some 22,000 ft. of the line, where the head is less than 300 ft., will be of woodstave construction.

Construction on the first stage of the development is well advanced and it is hoped to have the first machine at Tungatinah operating by mid 1953.

Second Stage of Construction. A 60 ft. high earth and rock-fill dam will be constructed at the outlet from Lake Echo, thus making available a storage capacity of 600 sq. mile feet. Into this storage will be diverted water from the Little Pine and Ouse Rivers. Another earth dam about 70 ft. high will be built across the River Dee six miles downstream to create a new lake to be called Dee Lagoon.

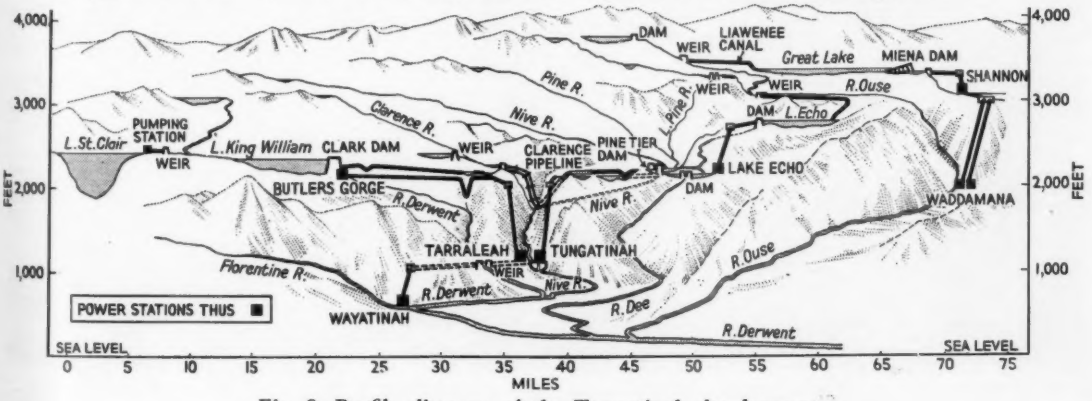

Fig. 9. Profile diagram of the Tungatinah development

The difference in levels between Lake Echo and Dee Lagoon will be about 600 ft., and in order to utilise this head a power station (to be known as Lake Echo power station) will be built on the banks of the new Dee Lagoon. It is proposed to install a single generating set in this station and the turbine will have a capacity of about 42,000 h.p.

Lake Echo will provide the main storage reservoir for Tungatinah power station, and it will be drawn upon mainly in times of drought. Lake Echo power station will therefore not operate continuously, but only when water is needed to augment the natural run-off from the Nive River catchment.

From Dee Lagoon, a tunnel will convey the water to Brady's Lake. This tunnel will be 2¼ miles long and will be of approximately 800 cusecs capacity.

This second stage of construction is as yet in the preliminary stages and it is not expected that it will be completed until 1955/6.

Fig. 10. Lake St. Clair pumping station

Tungatinah Power Station

The Tungatinah power development will regulate the run-off from approximately 400 sq. miles of country. The safe continuous flow available will be about 800 cusecs, and with an effective head of 1,005 ft. about 65,000 h.p. can be generated. However, in view of the considerable pondage available the station will be used to provide peak-load and spare-plant capacity. Turbines with a total capacity of 175,000

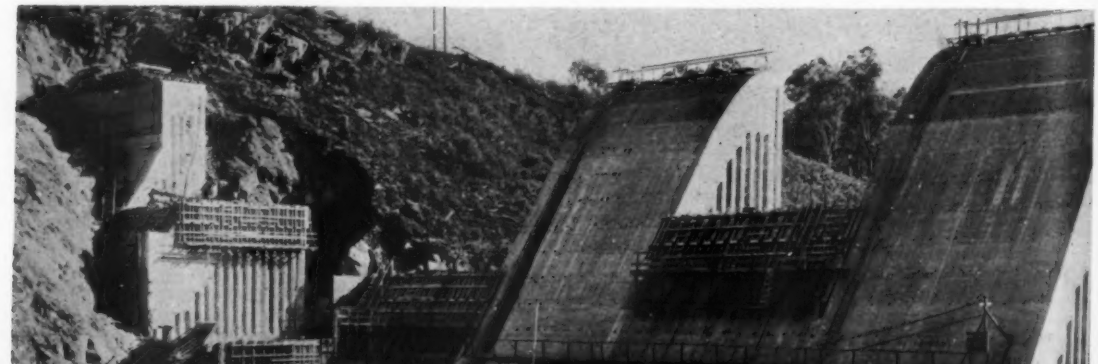

Fig. 11. Downstream view of Pine Tier dam during construction

h.p. will therefore be installed. The first unit of 35,000 h.p. is scheduled to be in operation mid 1953.

Wayatinah Power Development

The Wayatinah power station will be located on the Derwent River near its junction with the Florentine River. It will utilise the whole of the waters of the catchment areas in the upper reaches of the Derwent, the Clarence, the Nive, the Dee Rivers and part of the Ouse River. Most of this water will have been used on either one or two occasions at the Butlers Gorge, Tarraleah, Lake Echo, and Tungatinah power stations. In due course it will also be possible to divert the waters of the Florentine River through this station. The scheme as at present envisaged will comprise the following main features.

A concrete dam approximately 80 ft. high will be built on the Nive River about one mile downstream from Tarraleah power station. Water that has passed through Tarraleah and Tungatinah power stations, together with uncontrolled flow in the Nive River below the Clarence and Pine Tier diversions, will be diverted by this dam through a tunnel approximately 3½ miles long. This will pass across or below the Derwent River at a point a short distance below its junction with the Counsel River. At this point the tunnel flow will be augmented by the natural inflow to the River Derwent below Butlers Gorge. The tunnel of 2,800 cusec capacity will be continued for a distance of approximately 5 miles to the Wayatinah power station.

This station will have an initial capacity of approximately 140,000 h.p. divided between three or four units, operating under a head of 460 feet.

Preliminary construction in the form of access roads, camp sites, clearing and levelling has been started. In view of the urgent need for power for the manufacture of industrial products important to defence, work on this development will proceed as rapidly as finance allows. It is scheduled for completion in 1958 but it is hoped that this may be improved upon.

FUTURE PLANS

There is every indication that the demand for electric power in Tasmania will increase rapidly and that the developments described above will only barely satisfy demand when completed. The Commission is therefore conducting extensive surveys and investigations of other schemes with a view to further construction after completion of the present programme.

It may perhaps be of interest to explain that the power stations have been named with relevant words from the limited vocabulary of the now extinct Tasmanian aboriginal, i.e.:—

Waddamana	=	Noisy Water (Cascades)
Tarraleah	=	Brush Kangaroo.
Tungatinah	=	A Shower of Water (Waterfall).
Wayatinah	=	A Brook.

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Fifth Congress of the International Association for Hydraulic Research

The Fifth Congress of the International Association for Hydraulic Research which, as announced in our August issue, is to be held in Minneapolis on the campus of the University of Minnesota is the first meeting of the Association on the American continent. It will be held jointly with the Hydraulics Division of the American Society of Civil Engineers, the latter holding its second divisional meeting, and the Section of Hydrology of the American Geophysical Union will also hold a meeting on the University campus immediately preceding the Hydraulics Congress.

The opening session of the Congress will be in the auditorium of the Museum of Natural History on the morning of September 1. Preparations for the Convention have been undertaken by local committees established by the Northwestern Section of the American Society of Civil Engineers with headquarters at the St. Anthony Falls Hydraulic Laboratory of the University of Minnesota. The technical proceedings for the meetings, including 49 comprehensive hydraulics papers, are being issued immediately preceding the Congress, and form a 576-page volume involving the collaboration of 75 authors who include leading experts in the field of hydraulic research from some 20 countries.

The theme of the Congress is encompassed by four symposia toward which all technical papers are directed. Geophysical aspects of hydraulics make up the theme as follows: (a) Basic Relationships of Sediment Transportation by Flowing Water, (b) Density Currents, (c) Air Entrainment by Flowing Water, and (d) Waves, Beach Erosion, and Hydromechanics of Shore Structures.

The Hydraulics Congress will be in session from September 1 to 4 inclusive. The regional hydrology meeting of the American Geophysical Union will be held on August 31. Social evenings are planned, and the evening of September 3 is being arranged by the American Society of Civil Engineers, Hydraulics Division, as an open technical forum.

Speakers and participants from outside of the Americas will include Mr. Pierre Danel, Director, Neyrpic Hydraulic Laboratory, Grenoble, France; Dr. Wolmar Fellenius, Professor Emeritus of the Technical University, Stockholm, Sweden; Dr.-Ing. Milovan Goljevscek, Professor at the Technical University, Ljubljana, Yugoslavia; Professor J. Th. Thijsse, Director, National Hydraulic Laboratory, Delft, Netherlands; Sir Claude Inglis, Director of the Department of Scientific and Industrial Research, Hydraulics Research Organisation, London, England; Mr. A. Nizery, Chief Engineer, Hydraulic Laboratory Director, Electricité de France, Paris, France; Dr. L. Escande, Professor and Director, Hydraulic Laboratory, Toulouse, France; Prof. G. Evangelisti, University of Bologna, Bologna, Italy; Professor L. J. Tison, General Secretary, International Association of Hydrology, Gentbrugge, Belgium; Professor Masashi Hom-ma, Tokyo University, Tokyo, Japan; Mr. D. Doddiah, Assistant Director, Hydraulic Research Station, Mysore, India; and other well-known hydraulic engineers. Many leading American and Canadian scientists and engineers will actively participate in the meetings.

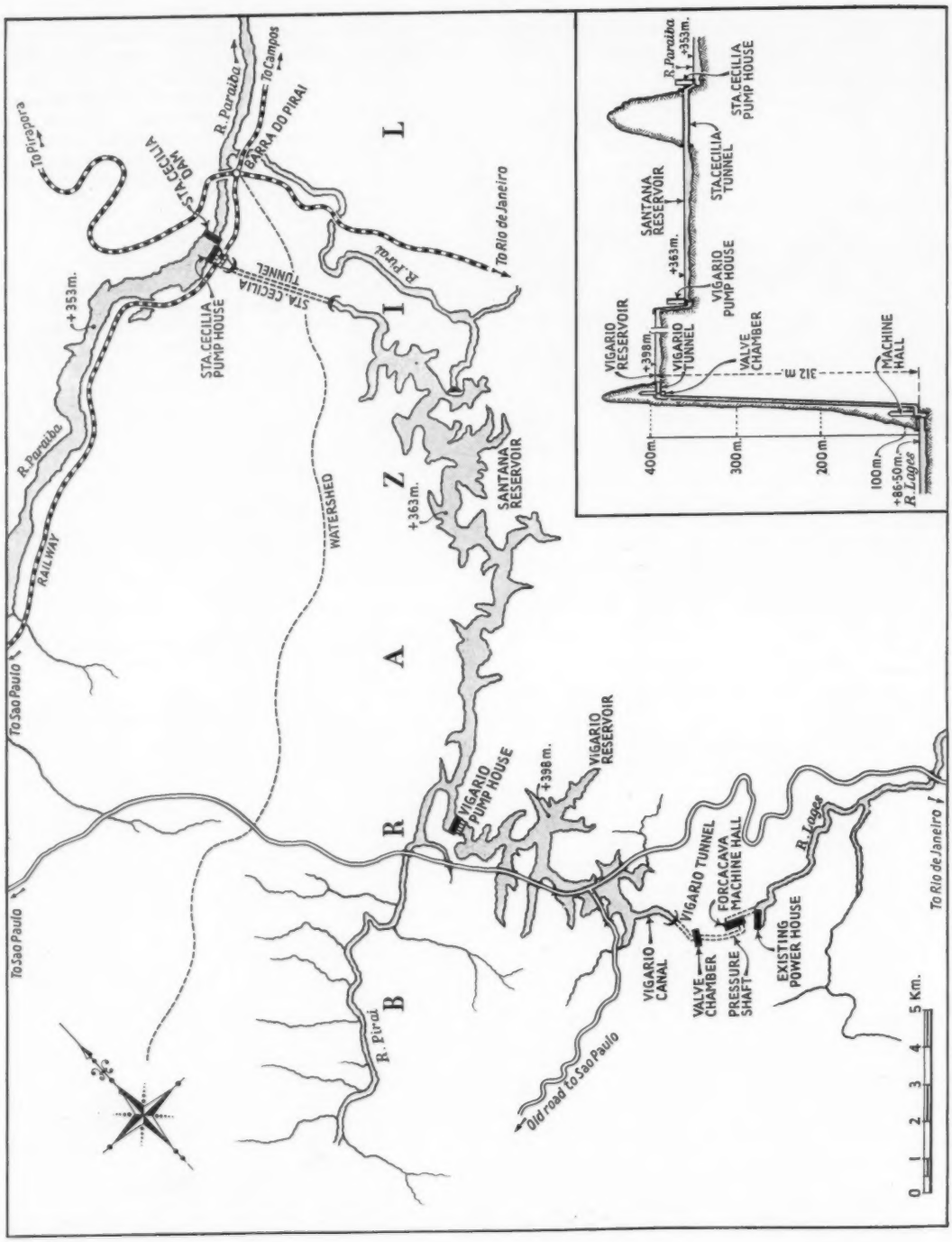

Fig. 1. Map and profile diagram of the Paraiba-Pirai diversion scheme

Fig. 2. View of the Lajes Valley showing the existing Fontes power station

The Forçacava Hydro-Electric Scheme

By PROF. DR. TECHN. L. v. RABCEWICZ, Stockholm.

The following article describes the work of excavation for a subterranean machine hall with the adjoining pressure shaft and access and discharge tunnels for the projected power plant at Forçacava, Brazil, with special reference to the working methods adopted in unstable rock. An article describing the scheme as a whole was published in our August issue.

PART ONE

THE rapidly increasing population and growing industrialisation of the states of Rio de Janeiro and Sao Paulo in Brazil, with their two large capitals now together totalling some 4·7 million inhabitants, have naturally been accompanied by an enormous demand for electric energy.

As part of the extensive programme for the supply of electric energy planned by the Cia de Carris, Luz e Força do Rio de Janeiro, which, under contract, is responsible for the supply of electricity to the two capital cities, the construction of a second large hydro-electric power plant was begun at the end of the second world war to supplement the existing power plant on the River Lajes at Fontes, some 80 km. west of Rio de Janeiro. This power plant makes use of the natural fall of the Serra das Aranas range at Fontes but takes its water from the large river Paraiba, which, for this purpose, is dammed at Sta Cecilia. Moreover, the Paraiba Pirai diversion scheme serves the purpose of increasing the flow to the existing Fontes plant. The scheme thus allows the Fontes plant to be run entirely by Paraiba water if necessary (see Fig. 1). The slight difference in altitude between the intake site and the watershed between the Rivers Lajes and Paraiba is overcome by pumping in two stages. The first pumping station, close to the dam at Sta Cecilia, with a capacity of 4×40 cu. m. per sec., raises the water 10 m. (max. 15 m.). Thence the water is conducted through a tunnel 3·3 km. in length and an open channel 2·5 km. in length, into the long, winding impounding lake of Santana in the valley of the River Pirai, which has a storage capacity of 20 million cu. m. The Pirai River discharges its water into this storage reservoir. At the south-western end of this reservoir a second pumping station with a capacity of 200 cu. m. per sec. raises the water 35 m. to the second storage reservoir Vigario, which has a storage capacity of 34 million cu. m. At its southern

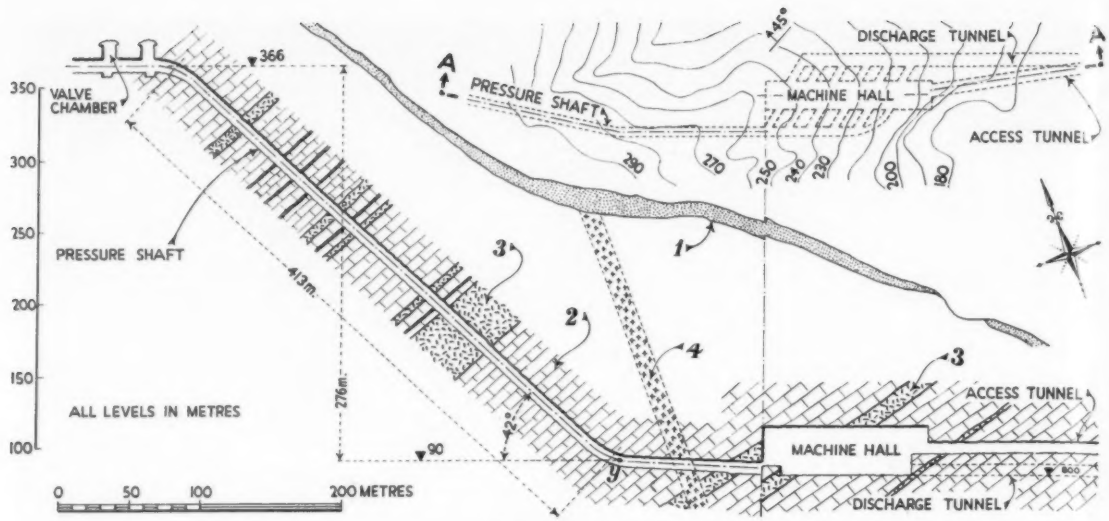

Fig. 3. Plan and section showing the geological conditions in the vicinity of the Forçacava pressure shaft and machine hall

end this lake is converted into a canal, which leads the water through a tunnel 690 m. in length to the subterranean valve chamber. From there an inclined pressure shaft conducts the water down to the machine hall, whence it discharges through a short submerged tunnel into the River Lajes, close to the existing Lajes power plant.

Six units with Francis turbines will be installed in the machine hall totalling 330,000 kW, viz., two units of 35,000 kW running at 600 r.p.m. with generators operating at 6,600 V 50 cycles, and four 65,000 kW units running at 375 r.p.m. with generators operating at 11,500 V 50 cycles. These units can also be operated at 60 cycles with normal speeds of 750 r.p.m. and 450 r.p.m. respectively. High-tension transmission lines will be built to transmit energy to Rio de Janeiro and São Paulo at 132,000 V and 230,000 V.

The underground type of machine hall with adjacent pressure shaft was chosen for this power plant for various reasons, such, for example, as economy in foreign currency as much less steel had to be imported for an underground pressure shaft; also there was

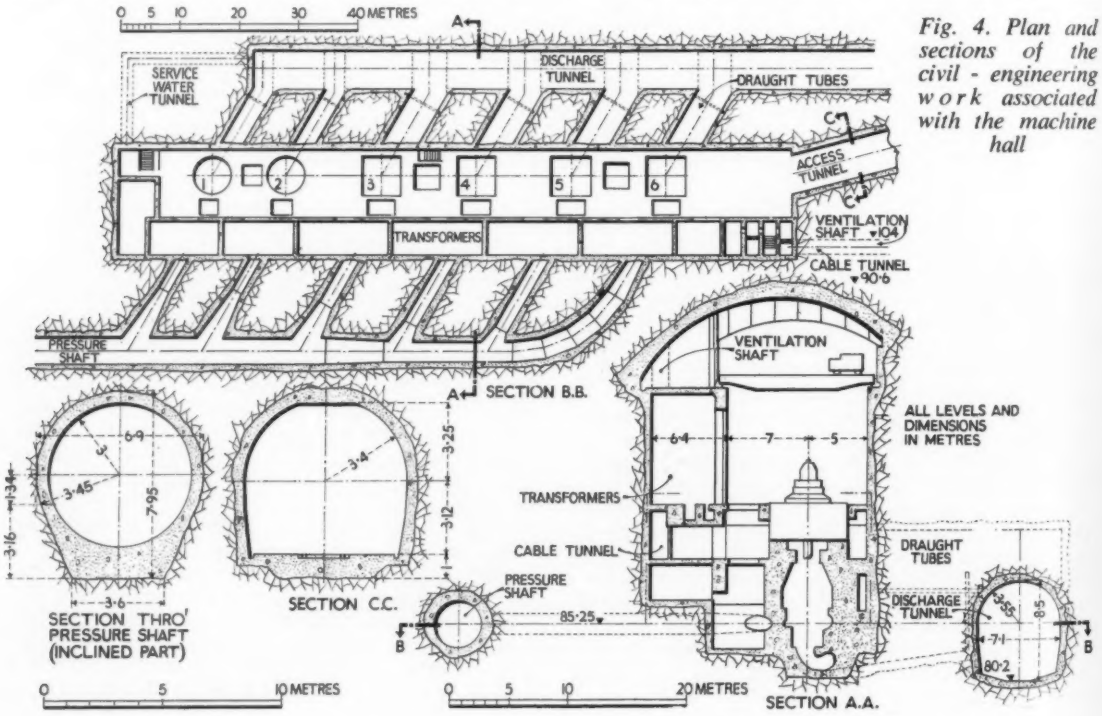

Fig. 4. Plan and sections of the civil - engineering work associated with the machine hall

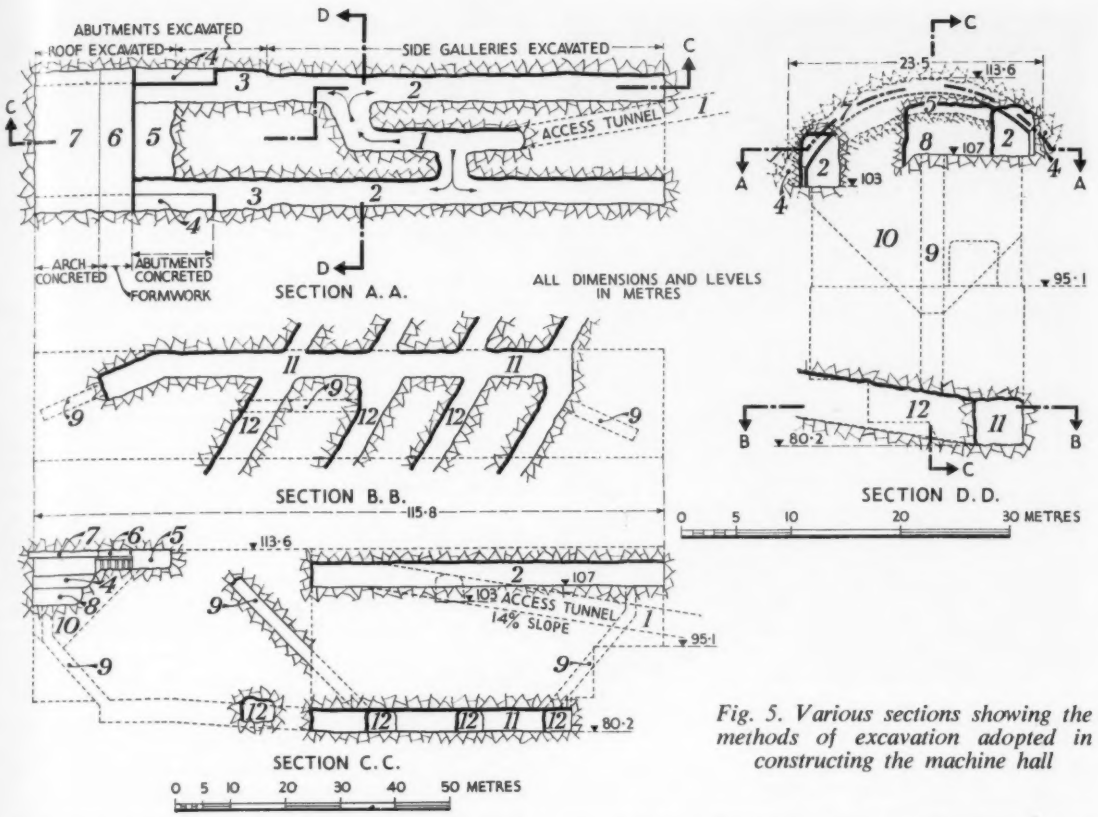

Fig. 5. Various sections showing the methods of excavation adopted in constructing the machine hall

inadequate space for a new power-station building and switchyard because of the existing plant. Finally the risk of landslides on the steep slopes of the Lajes valley had to be taken into account, and possibly strategic considerations as well.

The steel lining for the pressure-shaft distribution manifold and pressure branches was furnished by the American firm A. O. Smith, which was also responsible for its welding and erection, the latter work being executed by a Brazilian contractor. The thickness of the steel lining was based on the general assumption that in a gneiss of good quality, 70 per cent. of the water pressure had to be borne by the rock. In unfavourable places it was necessary to reinforce the steel lining to a corresponding extent.

The contract for the excavation of the pressure shaft and the machine hall as well as the access tunnel with adjoining distribution manifolds and draught tubes was placed with the Swedish contractors Svenska Entreprenad A.-B., SENTAB, of Stockholm, to whom the author of this article is permanent technical adviser. Very extensive concrete work had also to be carried out within the scope of this contract as the owners' original intention to place the concrete work in the hands of another contractor after the whole of the excavation had been completed could only be realised to a limited extent on account of the unfavourable condition of the rock.

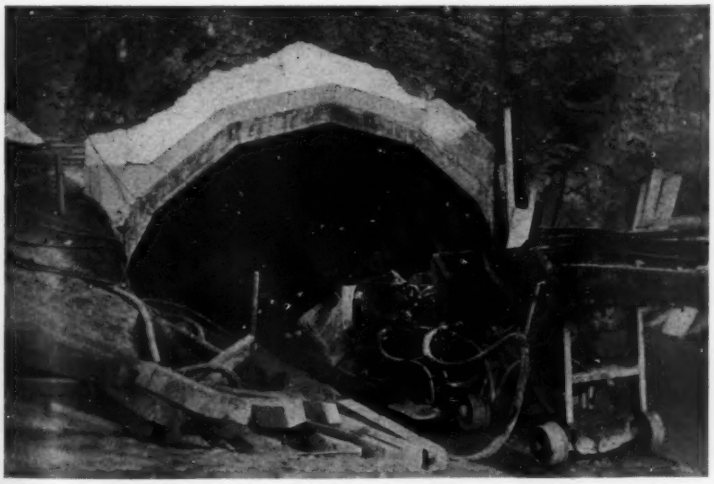

Fig. 6. Entrance to access tunnel, with an Eimco 40 in. shovel in the foreground

All other constructional work for the power plant was entrusted to the Cia Morrison & Knudsen do Brasil.

Within the scope of this article it is only intended to deal with the excavation of the pressure shaft

Fig. 7. Trackless haulage in the access tunnel

and machine hall, special attention being drawn to the methods of construction adopted in unstable rock.

Geological Conditions

The preliminary geological investigations were carried out in an exemplary manner. From the results of the diamond drilling undertaken over a network covering the whole area, an intimate knowledge of the geological conditions was obtained which excluded the possibility of major unforeseen contingencies. The pressure shaft had been located in a favourable position nearly perpendicular to the stratification of the gneiss. Less favourable was the machine hall, the longitudinal axis of which ran obliquely to the stratification. The bulk of the rock in the area concerned consisted of gneiss of fairly good quality. In certain places where the gneiss was not jointed, it was possible to excavate the rock in spans up to 8 m. and to leave it without support over quite a long period without risk of caving in. Such places were somewhat rare, however, and as a general rule it was necessary even in the sound rock to provide temporary or permanent support at an early stage in cavities of a similar size, whereas tunnels with spans of up to 4 m. were self-supporting.

As shown in Fig. 3, the gneiss was often intersected by fault zones of various thickness, mostly more or less parallel to the stratification. These zones showed all degrees of chemical and mechanical alteration from seamy rock to complete kaolinisation. Consideration difficulty was caused by a fault zone of large dimensions which ran obliquely through the machine hall and traversed the horizontal part of the pressure shaft and draught tubes to the discharge tunnel. This zone consisted of a completely kaolinised core, 2—4 m. thick, with adjacent layers of chemically less altered but heavily fractured and jointed rock showing different slip planes and slickensiding. The total extent of this bad zone measured, at right angles to the outermost slip planes, about 10 m. Moreover, some of these planes, and in particular, those in the lower part of the kaolinised core, were water bearing.

In addition to the faulting described, there was also a joint system dipping about 80° and running almost parallel to the longitudinal axis of the machine hall, where it was particularly pronounced, and repeatedly caused sudden falls of rock in huge blocks. In the pressure shaft, especially towards the centre portion, similar joints were also found. In those places, however, they did not cause any disturbance owing to the smaller span of the tunnel and the more favourable shape of its cross section.

The layer of diabase running obliquely through the rock encountered in the lower part of the pressure shaft did not cause any appreciable trouble.

Machine-hall Roof Arch

In order to obtain a point of attack for the excavation of the machine hall an access tunnel with a cross section of 53 sq. m. had to be driven (Figs. 6 and 7). Some 100 m. in front of the mouth of this access tunnel a transport tunnel with a cross section of 14 sq. m. was branched off and opened into the discharge tunnel with a downgrade of 12 per cent.

In the area of the machine hall the access tunnel was given an upgrade (see *1* in Fig. 5) up to the level of the two abutments of the roof arch, on each side of the machine hall. From this point side headings with a cross section of 16 sq. m. were driven along the abutments (see *2* in Fig. 5). These headings were then gradually enlarged by the excavation of the abutments *3*, closely followed by the mounting of the reinforcement bars and the pouring of the concrete *4*

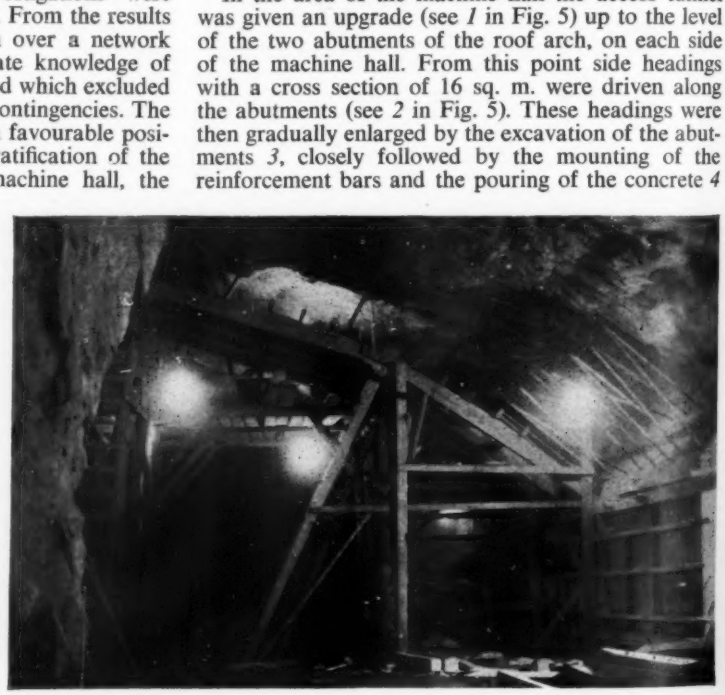

Fig. 8. Abutment and roof formwork in the machine hall side gallery

(see also Fig. 5, A—A and C—C and Fig. 8). The rock between the two side headings, where space had to be provided for the roof arch, was next blasted out, *5*, this being closely followed by the erection of a movable wooden arch serving as formwork, *6*, and the pouring of concrete, *7*. This work was done in sections of 6—8 m. Owing to the short time available, excavation and concreting had to proceed from both ends of the machine hall towards its centre. For a short period work was even carried on at a third point as well (Fig. 9).

The support of the unstable rock was so arranged that in the excavated zone *5*, the wooden framing was moved forward as soon as possible after blasting and loose parts underpinned against the forms by means of cut rails and precast concrete blocks (Fig. 10). This method was adopted on the assumption that the rock in a span of 24 m. × 8 m. would remain standing without caving in for a period of at least a few days. Fortunately, this assumption held true almost everywhere, in spite of the fact that the kaolinised zone traversed the whole roof. By dividing the excavation of the roof into small sections, it was fortunately possible to attack the bad zone running obliquely through the excavation area in stages. Those sections were naturally the most critical at which the bad zone appeared in the crown of the roof. In one such place a fall of a few cubic metres of rock once occurred which crushed the underlying form arch which had already been placed in position but not yet braced, but the incident was without evil consequences. The prevailing dry season during which the excavation of the roof arch was carried out, no doubt favoured the work owing to the fact that the chemically altered gneiss was much more stable in a dry condition. The completed concrete arch was then carefully grouted. Furthermore, deep holes were drilled through the arch into the rock above, in order to drain the zone close to the roof arch and counteract the effects of water pressure.

Simultaneously with the work on the roof arch, a bottom heading was driven from the transport tunnel into the machine hall (see *11*, Fig. 5). Furthermore, four tunnels *12* were driven through the machine hall at an oblique angle along the axes of the draught tubes and the pressure branches for power units Nos. 3—6. These tunnels served at the same time to provide an immediate point of attack for the pressure shaft.

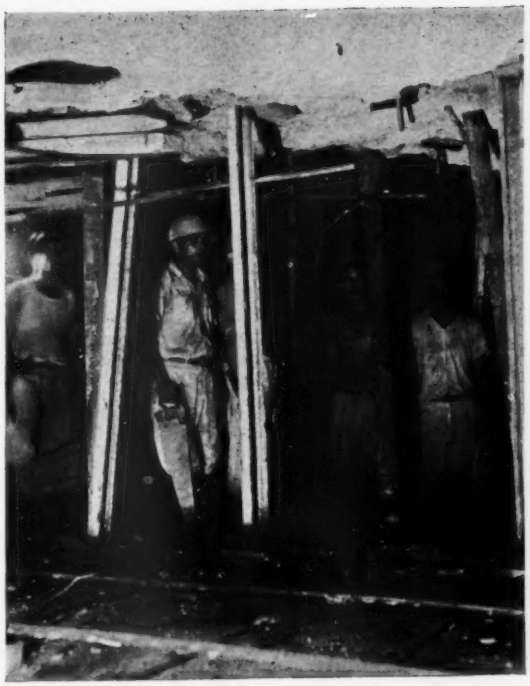

Fig. 10. Roof formwork and support of unstable rock

From tunnel *11*, Fig. 5, three inclines *9* were driven from the bottom of the machine hall up to the roof arch to serve as muck chutes. Two of these inclines were provisionally given the same slope as that for the pressure shaft through which the muck was intended to slide down by gravity only. From the experience gained in connection with the mucking process on these inclines it would still have been possible to change the original angle of inclination of the shaft (42°) but no correction was found necessary in this respect.

Finally, the excavation of the mass of rock in the machine hall was put in hand. This was done here by stoping against inclines *10* and *11*, the muck at the bottom being filled into dumping cars by loading machines. In order to increase the excavating capacity, the rock mass in the machine hall was also attacked from the access tunnel at elevation 95, where sufficient space was available for the employment of shovels for loading the muck. The maximum output at all loading places amounted to 10,000 cu. m. of solid rock per month. The average output was about 4,500 cu. m., due to various obstacles caused by bad rock; the highest hourly output was 35 cu. m.

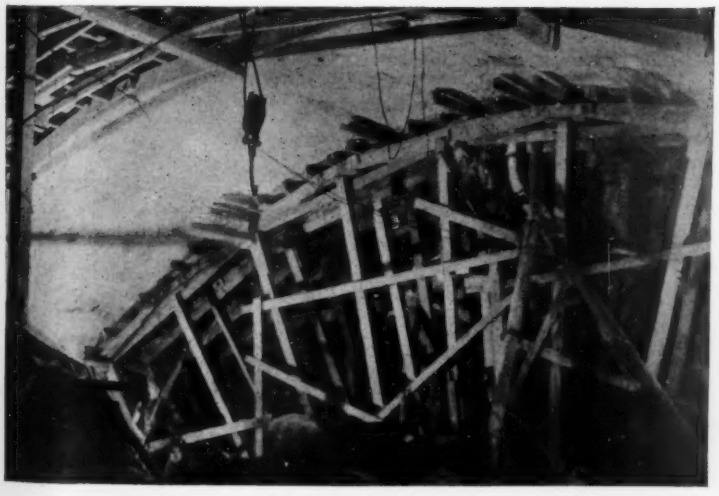

Fig. 9. Concreting of roof arch with pneumatic placers

(To be continued)

Stability of a Two-Surge-Chamber System

An analysis of the stability of a system involving two surge chambers, the one connected to the supply tunnel and the other to the tailrace tunnel.

By PROF. L. ESCANDE* and PROF. R. HURON

MOST modern hydro-electric stations have a supply tunnel operating under pressure, and in consequence are provided with a surge chamber at the head of the penstock. Some stations are located underground, and their tailrace tunnel, under certain conditions, may be placed under pressure. In such cases it is usual to provide a surge chamber at the junction between the turbine draught tube and the tailrace tunnel.

In the present study we shall examine the conditions of stability for the regulation of a turbine thus placed between two surge chambers, the one at the downstream end of the supply tunnel and the other at the upstream end of the tailrace (Fig. 1). We shall assume that these chambers are of constant section and are of the normal type without constriction.

Equations

Let:

H_0' be the difference between the upstream and downstream static water levels

P_{10}, P_{20} the losses in head in the supply tunnel and tailrace respectively for the normal full-load discharge Q_0

H_0 the difference in level between the water surfaces in the upstream and downstream surge chambers when the normal full-load discharge Q_0 is established

Z_1, X_1 the height of the upstream water level, at a moment t, above the static water level (Z_1), or the dynamic water level corresponding to full discharge ($X_1 = Z_1 + P_{10}$)

Z_2, X_2 the fall of the downstream water level, at a moment t, below the static level (Z_2) or the dynamic water level corresponding to full discharge ($X_2 = Z_2 - P_{20}$).

Should a change in conditions take place sufficient to influence the discharge Q_0, oscillations will commence in the two surge chambers, and in consequence, the head under which the turbines operate, at a time t, will not be H_0 but $H_0 + X_1 - X_2$. With normal governing the governor intervenes and modifies the discharge in a direction tending to keep the hydraulic power constant, assuming, of course, that the electrical load remains unchanged.

Neglecting variations in the efficiency of the conduit and of the turbine with the discharge, the discharge Q resulting from the action of the governor can be determined by the relationship:—

$$Q_0 H_0 = Q(H_0 + X_1 - X_2) \quad \ldots\ldots\ldots\ldots \quad (1)$$

The governor thus modifies the discharge in accordance with the oscillations, and these variations in discharge in their turn react on the oscillations, so that the problem consists of finding under what conditions the system will be stable, the oscillations in level and discharge dying away more or less rapidly.

Fundamental Ratios. Let us assume an instantaneous and complete stoppage of the turbine, and let us also neglect any losses of head. The supply and discharge systems can then be considered as independent. Oscillations will occur in the surge chambers C_1 and C_2, the amplitudes and periodicities of which may be denoted by Z_{1*}, Z_{2*}, T_1, T_2.

Then, if Q is the discharge at the moment t,

$$U_{10} = V_{10} = \frac{Q_0}{F_1};\ W_{10} = \frac{Q_0}{f_1};\ U_1 = \frac{Q}{F_1};\ W_1 = \frac{Q}{f_1};$$

$$V_1 = \frac{dZ_1}{dt}$$

$$U_{20} = V_{20} = \frac{Q_0}{F_2};\ W_{20} = \frac{Q_0}{f_2};\ U_2 = \frac{Q}{F_2};\ W_2 = \frac{Q}{f_2};$$

$$V_2 = \frac{dZ_2}{dt}$$

But $\quad T_1 = 2\pi\sqrt{\frac{L_1}{g}\frac{F_1}{f_1}}\ ;\ T_2 = 2\pi\sqrt{\frac{L_2}{g}\frac{F_2}{f_2}};$

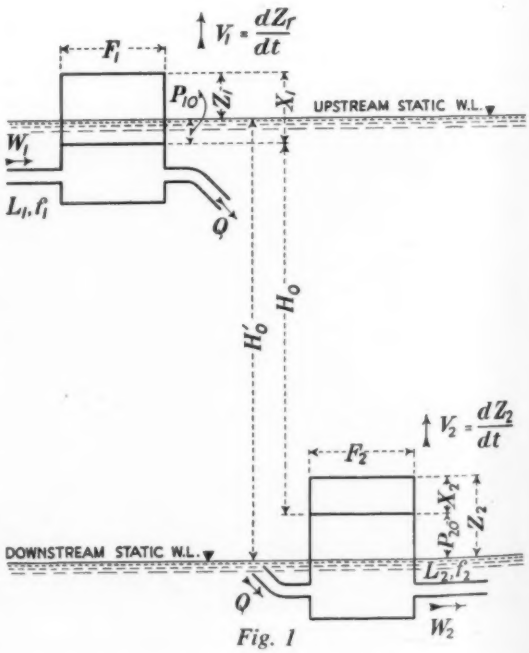

Fig. 1

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$$\therefore Z_{1*} = W_{10}\sqrt{\frac{L_1}{g}\frac{f_1}{F_1}} = U_{10}\frac{T_1}{2\pi}$$

$$Z_{2*} = W_{20}\sqrt{\frac{L_2}{g}\frac{f_2}{F_2}} = U_{20}\frac{T_2}{2\pi}$$

If P_1, P_2, P_{10}, P_{20} denote the head losses in the supply and discharge tunnels for discharges Q and Q_0 respectively, the classical ratios of Calame and Gaden may be applied.

$$z_1 = \frac{Z_1}{Z_{1*}}; \quad x_1 = \frac{X_1}{Z_{1*}}; \quad p_{10} = \frac{P_{10}}{Z_{1*}};$$

$$p_1 = \frac{P_1}{Z_{1*}}; \quad h_{10} = \frac{H_0}{Z_{1*}}; \quad z_2 = \frac{Z_2}{Z_{2*}};$$

$$x_2 = \frac{X_2}{Z_{2*}}; \quad p_{20} = \frac{P_{20}}{Z_{2*}}; \quad p_2 = \frac{P_2}{Z_{2*}};$$

$$h_{20} = \frac{H_0}{Z_{2*}};$$

$$u_1 = \frac{U_1}{U_{10}}; \; v_1 = \frac{V_1}{V_{10}}; \; w_1 = \frac{W_1}{W_{10}}; \; t_1' = \frac{t}{T_1}$$

$$u_2 = \frac{U_2}{U_{20}}; \; v_2 = \frac{V_2}{V_{20}}; \; w_2 = \frac{W_2}{W_{20}}; \; t_2' = \frac{t}{T_2}$$

Equations of the System. Seeing that in practice X_1 and X_2 are small with respect to H_0, equation (1) can be written:

$$u_1 = \frac{U_1}{U_{10}} = \frac{Q}{Q_0} = \frac{H_0}{H_0+X_1-X_2} = \frac{1}{1+\frac{X_1}{H_0}-\frac{X_2}{H_0}}$$

$$\# \; 1 - \frac{X_1}{H_0} + \frac{X_2}{H_0}$$

$$u_1 \# 1 - \frac{\frac{X_1}{Z_{1*}}}{\frac{H_0}{Z_{1*}}} + \frac{\frac{Z_{2*}X_2}{Z_{1*}Z_{2*}}}{\frac{H_0}{Z_{1*}}} \# 1 - \frac{x_1}{h_{10}} + m\frac{x_2}{h_{10}} \quad ..(2)$$

$$m = \frac{Z_{2*}}{Z_{1*}} = \sqrt{\frac{L_2 f_1 F_1}{L_1 f_2 F_2}} \quad .....(3)$$

where m is a constant depending only on the dimensions of the system and not upon the discharge Q_0. Similarly

$$u_2 = \frac{U_2}{U_{20}} = \frac{Q}{Q_0} \; \# \; 1 - \frac{1}{m}\frac{x_1}{h_{20}} + \frac{x_2}{h_{20}}$$

Thus $u_1 = u_2$ if $u_1 = u_2 =$

$$1 - \frac{x_1}{h_{10}} + m\frac{x_2}{h_{10}} = 1 - \frac{1}{m}\frac{x_1}{h_{20}} + \frac{x_2}{h_{20}} \quad .....(4)$$

The classical equations for the oscillations in a surge chamber give

For C_1

$$(5) \quad \begin{cases} v_1\frac{dv_1}{dz_1} + \frac{1}{2\pi}\frac{du_1}{dt'_1} + z_1 + p_1 = 0 \\ w_1 = v_1 + u_1; \; p_1 = p_{10}w_1^2; \; z_1 = x_1 - p_{10} \end{cases}$$

For C_2

$$(5') \quad \begin{cases} v_2\frac{dv_2}{dz_2} - \frac{1}{2\pi}\frac{du_2}{dt'_2} + z_2 - p_2 = 0 \\ w_2 = u_2 - v_2; \; p_2 = p_{20}w_2^2; \; z = x_2 + p_{20} \end{cases}$$

The expressions (4), (5) and (5') constitute the equations of the system.

Transformations. We have $dz_1 = dx_1$; $dz_2 = dx_2$, and from (2)

$$\frac{du_1}{dt'_1} = -\frac{1}{h_{10}}\frac{dx_1}{dt'_1} + \frac{m}{h_{10}}\frac{dx_2}{dt'_2}$$

$$= -\frac{1}{h_{10}}\frac{dx_1}{dt'_1} + \frac{1}{k}\frac{1}{h_{10}}\frac{dx_2}{dt'_2}$$

where

$$k = \frac{F_2}{F_1} \text{ and}$$

$$dt'_1 = \frac{dt}{T_1} = \frac{T_2}{T_1}\frac{dt}{T_2} = \frac{T_2}{T_1}dt'_2 = kmdt'_2$$

also

$$v_1 = \frac{V_1}{U_{10}} = \frac{V_1}{2\pi}\frac{T_1}{Z_{1*}} = \frac{1}{2\pi}\frac{dz_1}{dt}\frac{T_1}{Z_{1*}}$$

$$= \frac{1}{2\pi}\frac{dz_1}{dt'_1} = \frac{1}{2\pi}\frac{dx_1}{dt'_1}$$

$$p_1 = p_{10}(v_1+u_1)^2 = p_{10}\left(v_1 + 1 - \frac{x_1}{h_{10}} + m\frac{x_2}{h_{10}}\right)^2$$

$$p_1 = p_{10}\left(1 + \frac{1}{2\pi}\frac{dx_1}{dt'_1} - \frac{x_1}{h_{10}} + m\frac{x_2}{h_{10}}\right)^2$$

If, as in Thoma's classical theory, we regard

x_1, x_2, $\frac{dx_1}{dt'_1}$, as small with respect to a single surge chamber located downstream of the supply tunnel we have

$$p_1 \# p_{10}\left(1 + \frac{1}{\pi}\frac{dx_1}{dt'_1} - \frac{2x_1}{h_{10}} + m\frac{2x_2}{h_{20}}\right)$$

also

$$v_1\frac{dv_1}{dz_1} = v_1\frac{dv_1}{dt'_1}\cdot\frac{dt'_1}{dx_1} = v_1\frac{dv_1}{dt'_1}\cdot\frac{1}{2\pi v_1} = \frac{1}{4\pi^2}\frac{d^2x_1}{dt'^2_1}$$

Substituting in (5) we have

$$\frac{d^2x_1}{dt'^2_1} - 2\pi\left(\frac{1}{h_{10}} - 2p_{10}\right)\frac{dx_1}{dt'_1} + 4\pi^2\left(1 - \frac{2p_{10}}{h_{10}}\right)x_1$$

$$= -\frac{2\pi}{h_{10}}\left(\frac{1}{k}\frac{dx_2}{dt'_2} + 4\pi m p_{10}x_2\right) \quad .....(6)$$

and similarly (5') becomes

$$\frac{d^2x_2}{dt'^2_2} - 2\pi\left(\frac{1}{h_{20}} - 2p_{20}\right)\frac{dx_2}{dt'_2} + 4\pi^2\left(1 - \frac{2p_{20}}{h_{20}}\right)x_2$$

$$= -\frac{2\pi}{h_{20}}\left(k\frac{dx_1}{dt'_1} + 4\pi\frac{p_{20}}{m}x_1\right) .....(6')$$

where $t'_1 = kmt'_2$

NOTE. Although in a different form these equations are equivalent to those given by Dr. Ch. Jaeger in his general study of the stability of surge chambers which appeared in *Schweizerische Bauzeitung*, November and December 1943.

Conditions for Stability

New form of the equations. For a study of stability it is useful to take the same independent variable t in the two equations. Noting that

$$\frac{dx_i}{dt_i} = \frac{dx_i}{dt}\cdot\frac{dt}{dt_i} = T_i\frac{dx_i}{dt}$$

$$\frac{d^2x_i}{dt_i^2} = \frac{d}{dt}\left(T_i\frac{dx_i}{dt}\right)\frac{dt}{dt_i} = T_i^2\frac{d^2x_i}{dt^2} \quad (i = 1, 2)$$

and that as we have already seen

$$mk = \frac{T_2}{T_1} \quad ; \quad k = \frac{F_2}{F_1}$$

the system takes the form:

$$\left.\begin{aligned} \frac{d^2x_1}{dt^2} + a_1\frac{dx_1}{dt} + b_1x_1 &= A_1\frac{dx_2}{dt} + B_1x_2 \\ \frac{d^2x_2}{dt^2} + a_2\frac{dx_2}{dt} + b_2x_2 &= A_2\frac{dx_1}{dt} + B_2x_1 \end{aligned}\right\} \quad ..(7)$$

where

$$\left.\begin{aligned} a_1 &= -\frac{2\pi}{T_1}\left(\frac{1}{h_{10}} - 2p_{10}\right), \quad b_1 = \frac{4\pi^2}{T_1^2}\left(1-\frac{2p_{10}}{h_{10}}\right) \\ a_2 &= -\frac{2\pi}{T_2}\left(\frac{1}{h_{20}} - 2p_{20}\right), \quad b_2 = \frac{4\pi^2}{T_2^2}\left(1-\frac{2p_{20}}{h_{20}}\right) \\ A_1 &= -\frac{2\pi}{h_{10}}\cdot\frac{F_1}{F_2}\cdot\frac{T_2}{T_1^2}, \quad B_1 = -8\pi^2\frac{p_{10}}{h_{10}}\cdot\frac{F_1}{F_2}\cdot\frac{T_2}{T_1^3} \\ A_2 &= -\frac{2\pi}{h_{20}}\cdot\frac{F_2}{F_1}\cdot\frac{T_1}{T_2^2}, \quad B_2 = -8\pi^2\frac{p_{20}}{h_{20}}\cdot\frac{F_2}{F_1}\cdot\frac{T_1}{T_2^3} \end{aligned}\right\} \quad (8)$$

Conditions for Stability. Let us write

$$X_1(p) = \int_0^{+\infty} e^{-pt}\, x_1(t)\, dt$$

$$X_2(p) = \int_0^{+\infty} e^{-pt}\, x_2(t)\, dt$$

The functions X_1 and X_2 are the Laplace transformations of the unknown functions $x_1(t)$ and $x_2(t)$. Applying the classical formulae, system (7) becomes

$$\left.\begin{aligned} X_1(p^2+a_1p+b_1) - X_2(A_1p+B_1) &= \\ px_1(0)+\dot{x}_1(0)-a_1x_1(0)-A_1x_2(0) & \\ X_2(p^2+a_2p+b_2) - X_1(A_2p+B_2) &= \\ px_2(0)+\dot{x}_2(0)-a_2x_2(0)-A_2x_1(0) & \end{aligned}\right\} \quad .. (9)$$

It can thus be seen that the study of stability rests on the study of the roots of the equation

$$\Delta(p) = \begin{vmatrix} p^2+a_1p_1+b & -(A_1p+B_1) \\ -(A_2p+B_2) & p^2+a_2p+b_2 \end{vmatrix} = 0 \ldots . (10)$$

roots of which the real part must always be negative.

Developing the determinant of (10) we obtain the quartic equation

$$p^4+\alpha_1p^3+\alpha_2p^2+\alpha_3p+d_4=0 \ldots\ldots\ldots\ldots (11)$$

where

$$\left.\begin{aligned} \alpha_1 &= -2\pi\left[\frac{1}{T_1}\left(\frac{1}{h_{10}} - 2p_{10}\right) + \frac{1}{T_2}\left(\frac{1}{h_{20}} - 2p_{20}\right)\right] \\ \alpha_2 &= 4\pi^2\left\{\frac{1}{T_1^2}\left(1-\frac{2p_{10}}{h_{10}}\right) + \frac{1}{T_2^2}\left(1-\frac{2p_{20}}{h_{20}}\right) + \right. \\ &\qquad \left. \frac{2}{T_1T_2}\left[2p_{10}p_{20} - \left(\frac{p_{10}}{h_{20}} + \frac{p_{20}}{h_{10}}\right)\right]\right\} \\ \alpha_3 &= -\frac{8\pi^3}{T_1T_2}\left[\frac{1}{T_1}\left(\frac{1}{h_{20}} - 2p_{20} + \frac{4p_{10}p_{20}}{h_{10}}\right) + \right. \\ &\qquad \left. \frac{1}{T_2}\left(\frac{1}{h_{10}} - 2p_{10} + \frac{4p_{10}p_{20}}{h_{20}}\right)\right] \\ \alpha_4 &= \frac{16\pi^4}{T_1^2T_2^2}\left[1-2\left(\frac{p_{10}}{h_{10}} + \frac{p_{20}}{h_{20}}\right)\right] \end{aligned}\right\} \quad (12)$$

The necessary and sufficient conditions for the real roots of equation (11) to be negative—that is, for the system to be stable—are therefore (Routh's conditions)

$$\alpha_1>0,\ \alpha_2>0,\ \alpha_3>0,\ \alpha_4>0 \ ,$$
$$\Gamma = \alpha_3^2 - \alpha_1(\alpha_2\alpha_3 - \alpha_1\alpha_4) < 0 \quad \ldots (13)$$

As the problem involves a large number of parameters the general study of the conditions given by (13) from the values given by (12) is very complicated, but the insertion of numerical values enables a solution to be reached in all cases.

NOTE. In the case where it would appear of interest to retain the absolute characteristics of the physical system, we give below, and without explaining the calculation, the values of the coefficients α_i.

$$\left.\begin{aligned} \alpha_1 &= \frac{2g}{Q_0}\left[P_{10}\frac{f_1}{L_1} + P_{20}\frac{f_2}{L_2}\right] - \frac{Q_0}{H_0}\left(\frac{1}{F_1} + \frac{1}{F_2}\right) \\ \alpha_2 &= 4g^2\frac{P_{10}P_{20}}{Q^2}\cdot\frac{f_1}{L_1}\cdot\frac{f_2}{L_2} - \frac{2g}{H_0}\left(\frac{1}{F_1}+\frac{1}{F_2}\right) \\ &\quad \left(P_{10}\frac{f_1}{L_1} + P_{20}\frac{f_2}{L_2}\right) + g\left(\frac{f_1}{L_1F_1} + \frac{f_2}{L_2F_2}\right) \\ \alpha_3 &= \frac{2g^2}{Q_0}\cdot\frac{f_1}{L_1}\cdot\frac{f_2}{L_2}\left[\frac{P_{10}}{F_2} + \frac{P_{20}}{F_1}\right] - \frac{gQ_0}{F_1F_2H_0} \\ &\quad \left[\frac{f_2}{L_2} + \frac{f_1}{L_1}\right] - \frac{4g^2P_{10}P_{20}}{H_0Q_0}\cdot\frac{f_1}{L_1}\cdot\frac{f_2}{L_2}\left(\frac{1}{F_1}+\frac{1}{F_2}\right) \\ \alpha_4 &= \frac{g^2f_1f_2}{F_1F_2L_1L_2}\left(1 - \frac{2P_{10}}{H_0} - \frac{2P_{20}}{H_0}\right) \end{aligned}\right\} \quad (14)$$

First Note. The condition $\alpha_4>0$ furnishes the necessary condition

$$\frac{p_{10}}{h_{10}} + \frac{p_{20}}{h_{10}} < \frac{1}{2} \quad \ldots (15)$$

which is largely realised in practice. We know that in the case of a single surge chamber, Thoma's condition fixes a lower limit for the horizontal section of the chamber. In the present case we can obtain an equivalent condition by writing $\alpha_1>0$. From the formulae (14) we get

$$\frac{1}{F_1}+\frac{1}{F_2} < \frac{2gH_0}{Q_0^2}\left[P_{10}\frac{f_1}{L_1} + P_{20}\frac{f_2}{L_2}\right] \quad \ldots (16)$$

Thoma's limiting sections, relative to the upstream and downstream systems considered independently, are given by the expression

$$F_{10} = \frac{1}{2g}\left(\frac{Q_0}{f_1}\right)^2\frac{L_1f_1}{H_0P_{10}}$$

$$F_{20} = \frac{1}{2g}\left(\frac{Q_0}{f_2}\right)^2\frac{L_2f_2}{H_0P_{20}}$$

from which we see that equation (16) could be written

$$\frac{1}{F_1} + \frac{1}{F_2} < \frac{1}{F_{10}} + \frac{1}{F_{20}} \quad \ldots (16')$$

If, therefore, the two systems satisfy the appropriate condition laid down by Thoma ($F_1>F_{10}$, $F_2>F_{20}$), the necessary condition (16) is verified.

But this double verification is not sufficient to ensure stability. If each of the two chambers is at the limit of the appropriate Thoma condition the physical system will be unstable.* In fact, we have

$$\frac{1}{h_{10}} - 2p_{10} = 0 \qquad \frac{1}{h_{20}} - 2p_{20} = 0 \quad \ldots (17)$$

In these conditions α_3 reduces to a value that is always negative.

$$\alpha_3 = -\frac{8\pi^3}{T_1T_2}\cdot 4p_{10}p_{20}\left(\frac{1}{T_1h_{10}} + \frac{1}{T_2h_{20}}\right)$$

Consequently the two conditions of Thoma

$$\frac{1}{h_{10}} - 2p_{10} \leqq 0 \qquad \frac{1}{h_{20}} - 2p_{20} \leqq 0$$

are not sufficient, but it is necessary for at least one of the chambers to satisfy equation (16′).

Second Note. In the case where the head is high enough for the influence of the oscillations in the two surge chambers to become negligible, the system is obviously always stable. This can be demonstrated from equation (13). If we assume that

$$\frac{1}{h_{10}} = 0 \qquad \frac{1}{h_{20}} = 0$$

then

$$\alpha_1 = 4\pi\left(\frac{p_{10}}{T_1} + \frac{p_{20}}{T_2}\right) > 0$$

$$\alpha_2 = 4\pi^2\left(\frac{1}{T_1^2} + \frac{1}{T_2^2} + \frac{4p_{10}p_{20}}{T_1T_2}\right) > 0$$

$$\alpha_3 = \frac{16\pi^3}{T_1T_2}\left(\frac{p_{20}}{T_1} + \frac{p_{10}}{T_2}\right) > 0$$

$$\alpha_4 = \frac{16\pi^4}{T_1^2T_2^2} > 0$$

from which it can be calculated that

$$\Gamma = \alpha_3^2 - \alpha_1(\alpha_2\alpha_3 - \alpha_1\alpha_4)$$

$$= -\frac{256\pi^6}{T_1T_2}\left\{p_{10}p_{20}\left(\frac{1}{T_1^2} - \frac{1}{T_2^2}\right)^2 + \frac{4p_{10}p_{20}}{T_1T_2}\left[p_{10}p_{20}\left(\frac{1}{T_1^2} + \frac{1}{T_2^2}\right) + \frac{p_{10}^2p_{20}^2}{T_1T_2}\right]\right\}$$

or $\Gamma = \alpha^2_3 - \alpha_1(\alpha_2\alpha_3 - \alpha_1\alpha_4) < 0$

* This property is general, for $-\alpha_1$ is the sum of the roots of equation (11). If this sum is zero we also have $R(\sum p_i)=0$, and roots having real positive values will inevitably occur.

Application

For any given project the sections F_1 and F_2 for the lower and upper surge chambers will first be calculated, without reference to the problem of stability and taking account only of limiting the value of the oscillations to a convenient value. Thus a system will be formulated determined by the values of

$$\begin{array}{cccccc} Q_0 & & & & & \\ L_1, & f_1, & P_{10}, & F_1, & Z_{1*}, & T_1 \\ L_2, & f_2, & P_{20}, & F_2, & Z_{2*}, & T_2 \end{array}$$

It then remains to satisfy that the five conditions of stability are satisfied

$$\alpha_1>0 \quad \alpha_2>0 \quad \alpha_3>0 \quad \alpha_4>0 \quad \Gamma<0$$

Should this not be the case the calculation should be repeated with higher values of F_1 and F_2.

We have thought it of interest to ascertain, for a number of cases, the limiting values H_{OL} of the normal head H_0 below which the system becomes unstable and to compare these values with the limiting values H_{OL1} and H_{OL2} given by Thoma's condition for the supply system (H_{OL1}) and the discharge system (H_{OL2}) respectively.

We commence with the following quantities, which are maintained constant:

$Q_0 = 20$ cu. m. per sec.

L_1 =	1000 m.	L_2 =	700 m.
f_1 =	10 sq. m.	f_2 =	10 sq. m.
F_1 =	40·8 sq. m.	F_2 =	79·3 sq. m.
Z_{1*} =	10 m.	Z_{2*} =	6 m.

and we have calculated H_{OL}, H_{OL1}, H_{OL2} for five differents sets of values of head losses P_{10}, P_{20} as given in Table I together with relative values p_{10}, p_{20}.

TABLE I

No.	P_{10}	P_{20}	p_{10}	p_{20}
	m.	m.		
1	1	0·36	0·10	0·06
2	0·91	0·36	0·091	0·06
3	0·833	0·36	0·0833	0·06
4	0·70	0·36	0·070	0·06
5	0·50	0·36	0·050	0·06

Figs. 2 to 6 give curves of α_1, α_2, α_3, α_4 Γ, and show the values of H_{OL} obtained in each case as well as that of H_{OL1} and H_{OL2} calculated by Thoma's formula.

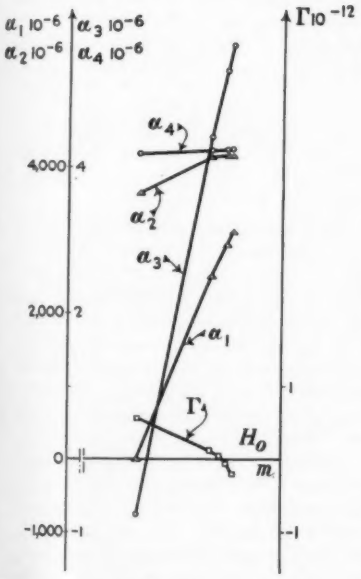


Fig. 2

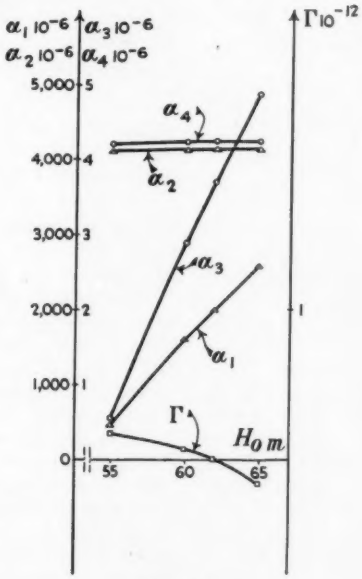


Fig. 3

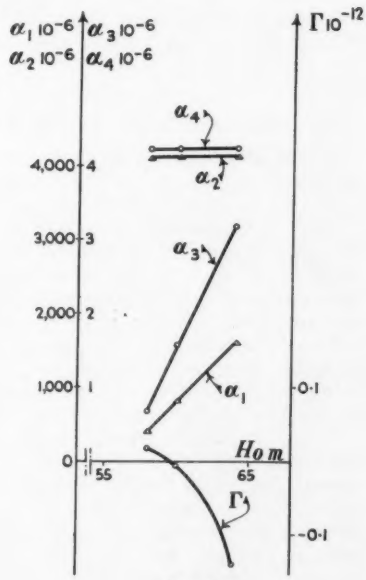


Fig. 4

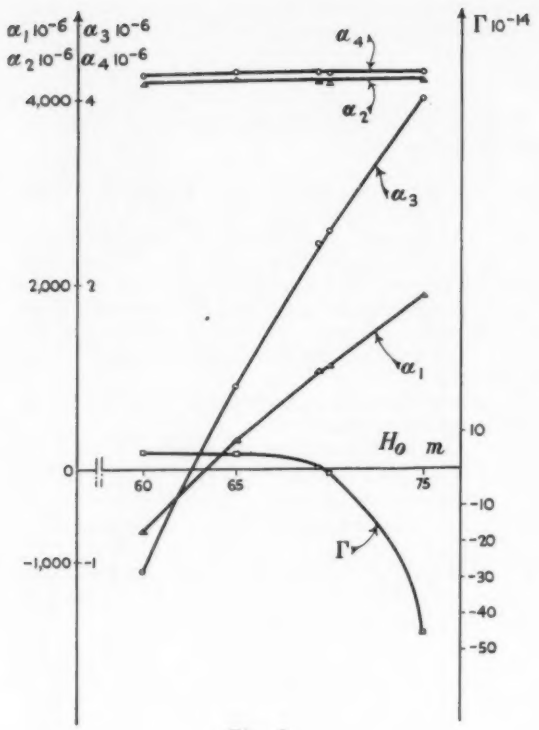


Fig. 5

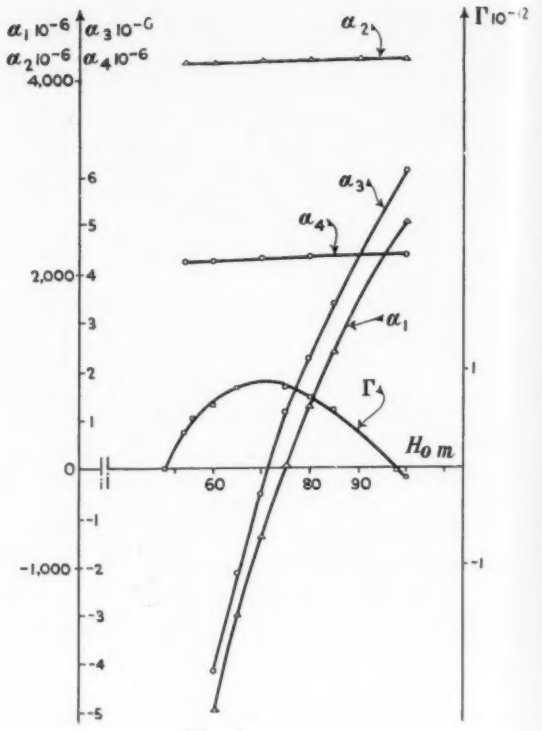


Fig. 6

Table II gives H_{OL}, H_{OL1}, H_{OL2} for each of the five cases.

TABLE II

No.	H_{OL}	H_{OL1}	H_{OL2}
	m.	m.	m.
1	61·8	50	50
2	62	55	50
3	59·7	60	50
4	69·5	71·4	50
5	98	100	50

An examination of these results shows that if $H_{OL1} = H_{OL2}$ their value is less than H_{OL}. If H_{OL1} and H_{OL2} are different, H_{OL} may be greater than the other two or it may be between them, but it is always larger than the smaller of the other two. This is in accordance with the general theoretical analysis given above under "Conditions for Stability"—that if Thoma's condition is complied with exactly ($F_1 = F_{10}, F_2 = F_{20}$) for both the supply system and for the discharge system, stability will not be secured. On the other hand, in stable conditions Thoma's relationship is largely satisfied for at least one of the systems.

Hydraulics Conference in Algiers, 1954

Société Hydrotechnique de France is organising a three-day conference on hydraulics in Algiers on April 12, 13 and 14, 1954, in conjunction with the Twelfth International Congress on Irrigation and Drainage which will be held at the same place on April 15, 16 and 17. The subjects studied during the three-day conference will be rain, evaporation, filtration and flow. The two series of conferences will be followed by scientific excursions in North Africa (Algeria, Morocco, Tunisia) and in France. Those taking part in the three-day conference will be eligible for the Twelfth International Congress and vice versa.

Those wishing to submit papers or participate in the discussions in the three-day conference should communicate with Société Hydrotechnique de France at 199, Rue de Grenelle, Paris VII. Three copies of a précis of the proposed paper should be submitted as soon as possible, and ten copies of the full text of accepted papers should be sent in before December 31, 1953. Enquiries regarding arrangements, and requests for forms of application for membership of the conference, can now be sent in to Société Hydrotechnique de France.

British Standards 1953 Yearbook. The British Standards Institution, 2 Park Street, London, W.1; price 12s. 6d.

The 1953 edition of the British Standards Yearbook has just been published and gives a list of the 2,000 British Standards current at the end of March 1953, with a brief description of the subject matter of each. A comprehensive index simplifies reference. The Yearbook gives the usual information on the membership of the General Council, the Divisional Councils and the Industry Standards Committees, together with the names of the representatives on the main Special Committees and Advisory Committees. The Yearbook gives a list of the British Standards under which the Institution's certification trade marks are used; particulars of the work in hand of all the Industry Standards Committees are also given.

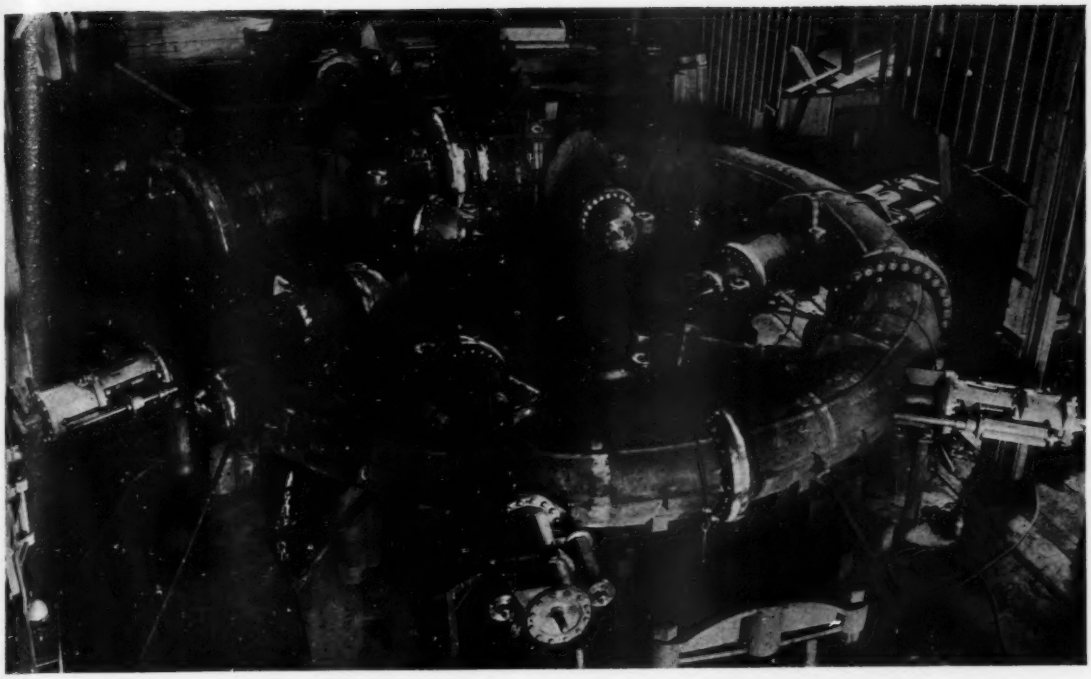


Fig. 1. Latest design of nozzle assembly for 62,000 h.p. turbine

A Six-Nozzle Pelton Turbine

An account is given of the considerations which led to the adoption of a six-jet design for the Bridge River plant of the British Columbia Electric Co. Ltd.

IN common with other regions depending on hydro-electric power derived from snowfields, British Columbia has been concerned to develop deep high-head storage basins which can be tapped in the winter months when the general freeze-up causes river flow to diminish. With this end in view the British Columbia Electric Co. Ltd. decided to develop the Bridge River, which has its origin in a rugged mountain area about 130 miles north-east of Vancouver. This river rises on the eastern flanks of the Coast Range and flows in a narrow valley in a generally eastern direction to join the Fraser River above Lillooet.

In the present state of development a storage dam has been built having a capacity of 170,000 acre ft. and some 40 miles below it a diversion dam has been constructed to direct the water into a 14 ft. 3 in. diameter tunnel at the downstream end of which penstocks carry the flow to the power station on the shores of Seton Lake, about 1,200 ft. below. As yet the power station is not fully equipped but a fourth unit has recently been added. Ultimately the plant will comprise ten multiple-jet Pelton generator sets of 50,000 kVA capacity each but some of these will be housed in a separate power house located about half a mile away and supplied by a new tunnel. Before these can be supplied with water, however, it will be necessary to increase the height of the Lajoie dam until it is capable of impounding 570,000 acre ft. This work is now in hand

The object of this article is not, however, to discuss the Bridge River development in its wider aspects,

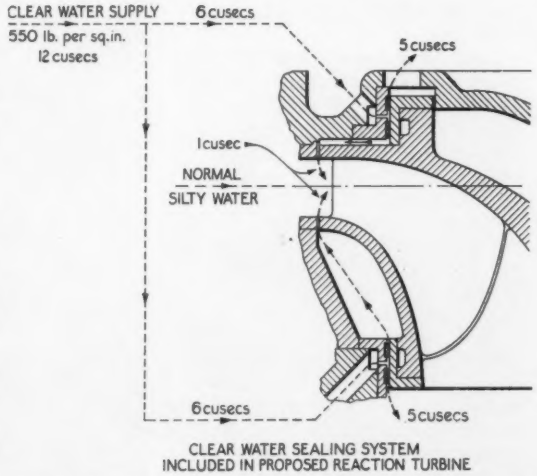


Fig. 2. Auxiliary water-seal system for Francis turbine for use with silty water

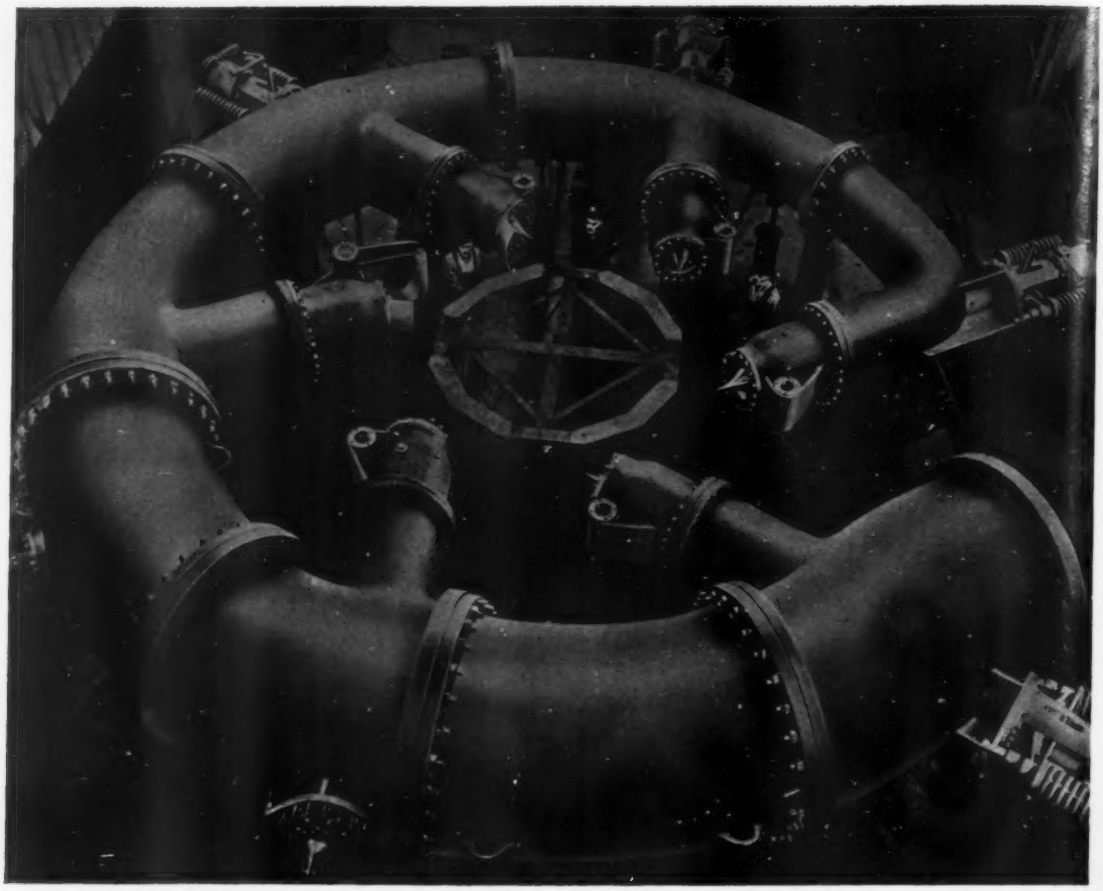


Fig. 3. Nozzle assembly for the first turbine

but rather to pick on a point of singular interest and to enter into the considerations which led to the choice of six-nozzle, vertical-shaft Pelton units for the Seton Lake station.

Like most waters derived from snowfields and glaciated valleys, that of the Bridge River is heavily charged with silt. As the accompanying analysis shows, the high proportion of silica causes the silt to have a particularly destructive effect on turbine runners. When the problem of using this water was referred to The Pelton Water Wheel Company of San Francisco they recommended a Francis-type turbine fitted with an auxiliary water-seal system fed with clean water (Fig. 2). This arrangement would have required the injection of clean water at the rate of 12 cusecs and at a pressure of 550 lb. per sq. in. and would have penalised the turbine efficiency to the extent of one or two per cent.

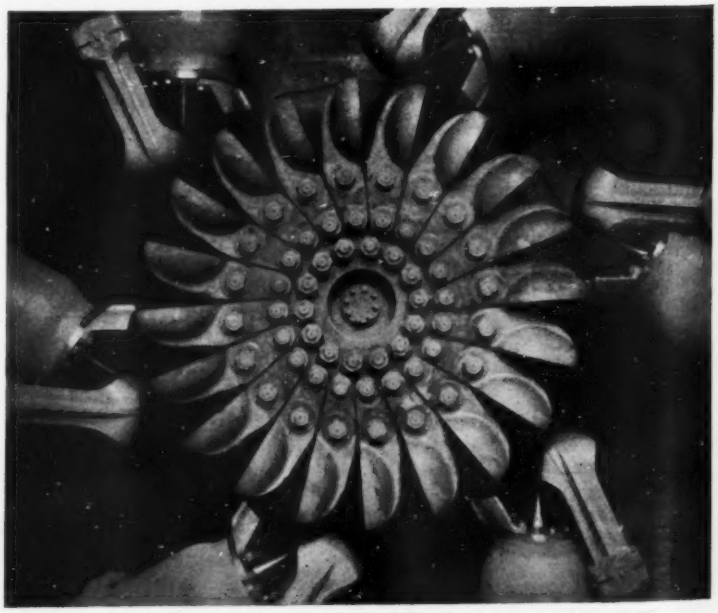


Fig. 4. The wheel in position between the nozzles

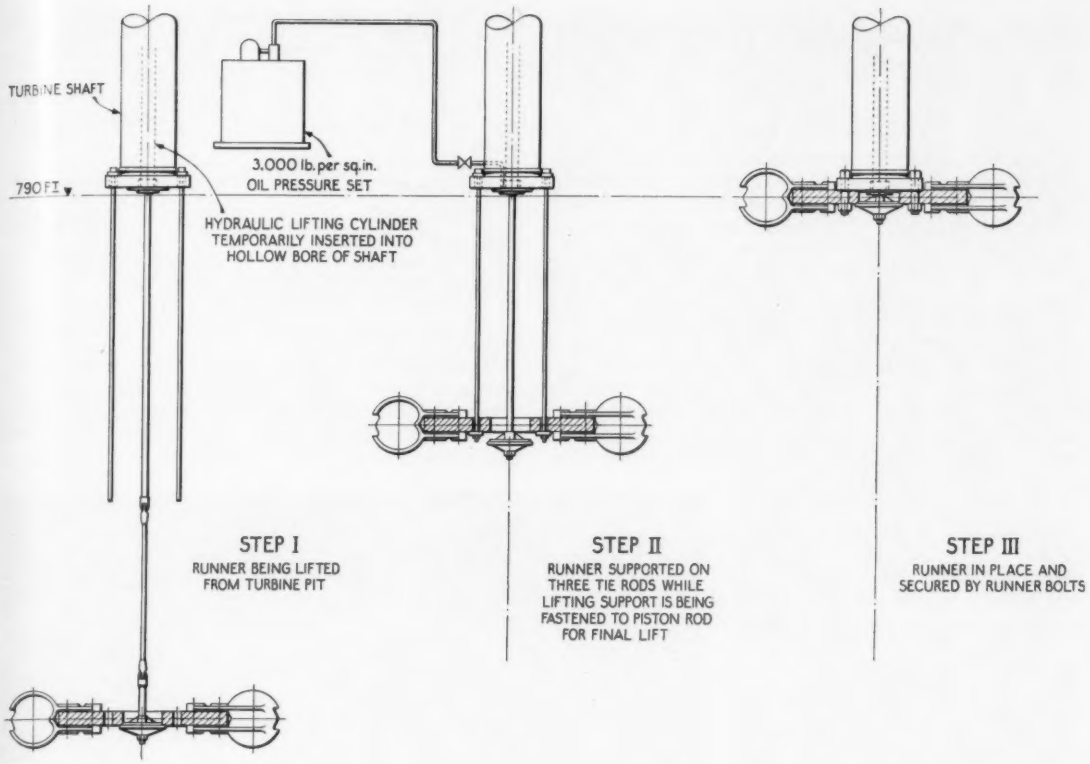


Fig. 5. Method of raising the runner from the turbine pit to its working position

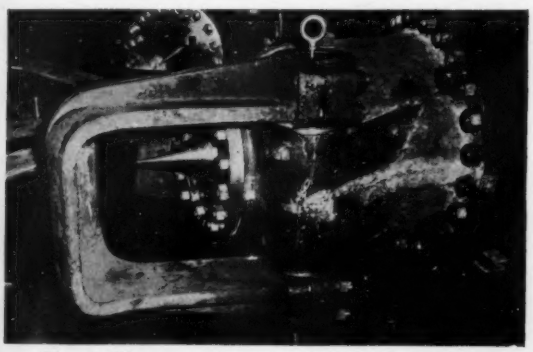


Fig. 6. Close-up view of nozzle-tip assembly

This appeared to the makers to be justifiable in view of the fact that the expedient would have enabled the normal 0·015 in. between the runner and the

Analysis of Sediment in Water

Silica	65·34%
FeO	4·18%
Al_2O_3	17·37%
$CaCO_3$	2·68%
$MgCO_3$	8·36%
TiO_2	0·17%
MnO	0·05%
Na_2O	1·52%
Ti_2O	0·25%

sealing ring to have been well maintained whereas the seepage of silt-laden water would have quickly widened the clearance, giving rise not only to loss of

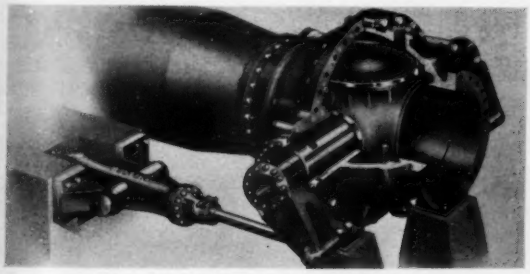


Fig. 7. Main spherical valve open

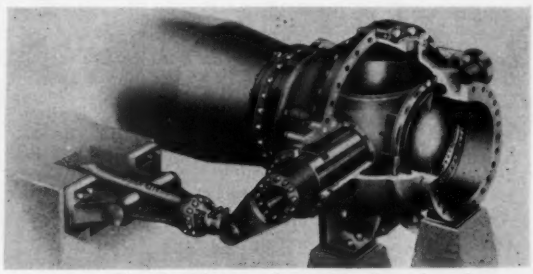


Fig. 8. Main spherical valve closed

efficiency but also to a serious maintenance problem.

The B.C. Electric Company, however, favoured a turbine of impulse design, experience having indicated that silt erosion has very little effect on the operating efficiency of a Pelton wheel and that the repair of the buckets by welding, without having to remove the runner, was relatively inexpensive and easily effected. The turbine makers investigated various possibilities but finally came to the conclusion that a six-nozzle vertical-shaft construction had points of advantage over the double-nozzle double-overhung design and even over the four-nozzle vertical shaft machine which they had actually contracted to construct. Table I gives the essential points of comparison between the four-jet and six-jet construction. The Pelton Water Wheel Company had already established in previous researches that the angularity between two adjacent jets could be brought down to 55° without any adverse effects on efficiency. But the overall effect of using six jets had yet to be ascertained. To this end casing studies were made to determine the fluid path which would give optimum results, together with housing studies to establish the best shape to clear the water from the upper runner discharge. Other investigations were concerned with ensuring a streamlined flow in the nozzle, as any turbulence causes the jet to lose shape with resulting loss in efficiency. Tests with curved vane sections such as are used in short-radius elbows did not give satisfactory results, but contrary to what had previously been thought, a straight-pattern grid at the entrance to the nozzle resulted in an admirable jet.

To solve the housing problem, 25 different versions were constructed and a variety of baffles tried out, using scale models. Dummy jet deflectors and jet protectors were provided to simulate the actual operating conditions, although no attempt was made to control the model outputs by these means, the idea merely being to show whether splash conditions detrimental to the efficiency could be avoided. Eventually a peak efficiency of 89 per cent. was obtained with the arrangement finally adopted, this being with a wheel mounting 20 #17 buckets. At this stage of the investigation it was considered necessary to conduct tests under a head of 250 ft. and to try out the effect of 20 #18 buckets on the wheel. In these conditions a one-fifth scale model gave an efficiency of 89·8 per cent. This result was eminently satisfactory, particularly as the equivalent practical head, corresponding to 250 ft. for the model, was 1,250 ft. and was thus substantially higher than the design head of 1,118 ft.

Table I—Basic comparison of four- and six-nozzle turbines, 62,000 h.p., 300 r.p.m., 1,118 ft. head

	Four-nozzle turbine	Six-nozzle turbine
Specific speed per jet	5·77	4·71
Ratio $\frac{\text{Runner diameter}}{\text{Jet diameter}}$	10·4	12·7
Efficiency #17 bucket	87	88·75
Efficiency #18 bucket	88·1	89·35
Relative strength of bucket attachment to wheel centre	1	1·21

In the practical design of the first unit, the casing, shown in Figs. . and , consists of eight nozzle and elbow sections constructed in cast steel. The section for the No. 1 nozzle weighs no less than 25,000 lb. and the entire structure 150,000 lb. In later units

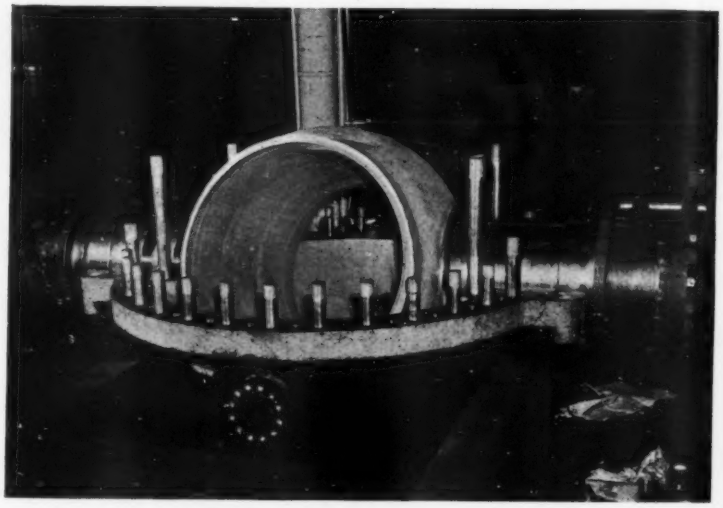


Fig. 9. Main spherical valve in course of erection

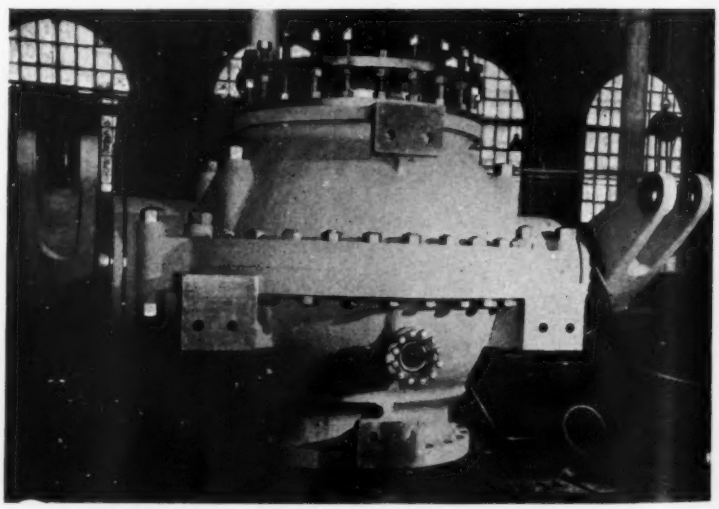


Fig. 10. The completed valve in the makers' works

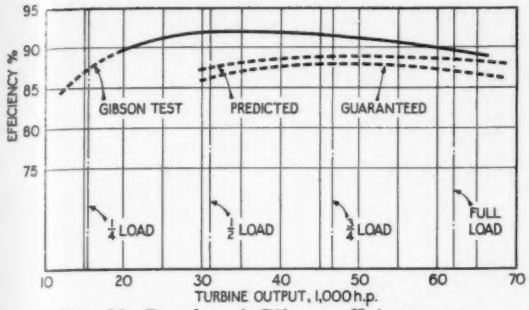


Fig. 11. Results of Gibson efficiency test

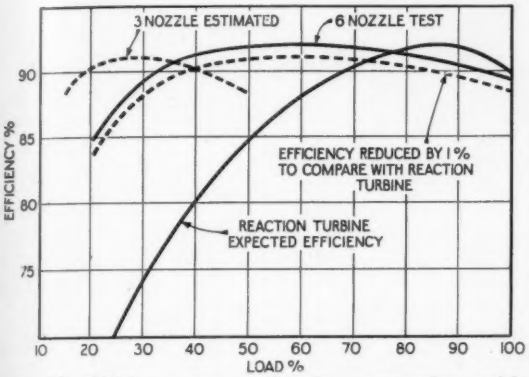


Fig. 12. Efficiency curves showing comparison with three-nozzle turbine and with reaction turbine

(Fig. 1) the number of casing sections were reduced in that some of the joints were made by welding and stress relieving. These casings were manufactured at the Vancouver Engineering Works who were also responsible for testing them up to a pressure of 935 lb. per sq. in. The separate, replaceable needle seats are made of stainless steel, and the needle points are of the same material. The runner is made up of 20 weldable cast-steel buckets, each attached to the forged steel disc by two interference bolts. To obtain the necessary degree of forced fit, the bolts were ground to ensure the desired interference; the smaller bolts, 3¼ in. nominal size, required a load of 50 tons while the outer ring of 4 in. nominal diameter bolts required a pull of 75 tons.

No bucket troubles were experienced for ten months, equivalent to 750 million stress reversals, after which a curious vibration was noticed in the No. 1 turbine. As it was inconvenient to shut down the unit immediately, it was run in this condition for 12 hours, after which the vibration was found to be due to a 4 in. bolt being missing from one of the buckets. This disconcerting discovery was capped by the fact that the bolt fitted quite loosely into the hole in spite of the original interference fit. A careful check revealed not only that the bucket lug in question contained five cracks but also that there were similar cracks in the lugs of other buckets. These cracks were generally located over the 4 in. bolt holes at the highest point of loading. Detailed investigation traced the cracks to foundry origin and that they had been present since the day the buckets were cast. What is particularly interesting is that although the stress-resisting cross section had been reduced to about one-half, thus increasing the stress concentration around the edge of the crack to something like four to six times the design value, no fatigue effects were discernible, in spite of the 750 million stress reversals. Obviously, however, a new foundry technique was called for, and it is now routine practice for the first bucket of every run to be examined by breaking the lugs and cutting up the bowls to ensure that it is sound throughout. All the succeeding buckets in the run are subjected to a thoroughgoing inspection in which use is made of Magnaflux X-ray, Zyglo and the supersonic Reflectoscope.

A Gibson efficiency test conducted in accordance with the A.S.M.E. Test Code gave the results shown in Fig. 11. It will be seen that a maximum of 92 per cent. is reached, while the curve remains consistently over the 90 per cent. ordinate within the range 21,000 to 58,000 h.p. Such a performance is very gratifying, particularly when related to the guaranteed and predicted efficiencies. Quite apart from the justification of the six-nozzle design on efficiency grounds, its amenability to maintenance gives added point to the B.C. Electric Company's choice. The vertical impulse turbine is peculiarly accessible, and the main bearing, deflector servomotors and linkages and the needle servomotors can readily be inspected and kept in good order. A manhole in the wheel-pit liner gives immediate access to the wheel and nozzles, and a plank floor laid on a permanent steel framework about 7 ft. below the runner affords excellent convenience for dismantling and assembly. Fig. 5 indicates the ease with which the runner can be removed. For this purpose a hydraulic cylinder is placed in the hollow 6 in. bore of the shaft and used to raise and lower the runner as required. It can then be brought out of the pit via the tailrace and raised to generator floor level through an access hole. In this way it is possible to undertake maintenance work on the power-house floor and so reduce outages to a minimum. In practice it has been found that the time required to take the turbine off the line, to remove the runner, substitute a spare and to return the turbine to the line, is 16 hours.

The high percentage of silica in the silt carried by the water naturally gave rise to surmises about erosion problems. These have not, however, proved to be formidable, as periodic grinding at inspection periods greatly retards the rate of erosion. Cavitation tendencies have been minor and can be controlled with a small amount of preventative maintenance. It is estimated that a five-year wheel life can be expected with a normal amount of maintenance. It must be remembered that each bucket passes through a jet at the rate of 30 times per second, and having regard to this fact, wear has been remarkably small. Also the six-nozzle configuration results in a small wheel size in relation to the power developed.

In conclusion it can be affirmed that the vertical six-nozzle impulse turbine has proved to have an excellent efficiency with all six nozzles in operation, and in addition, high efficiency at part load can be maintained by having an appropriate number of jets in service for practically any specific load. Fig. 12 gives relative curves, furnished by the makers, to show the overall performance compared with a reaction turbine of equivalent power with and without allowances for the loss in the tailwater in the case of the impulse design.

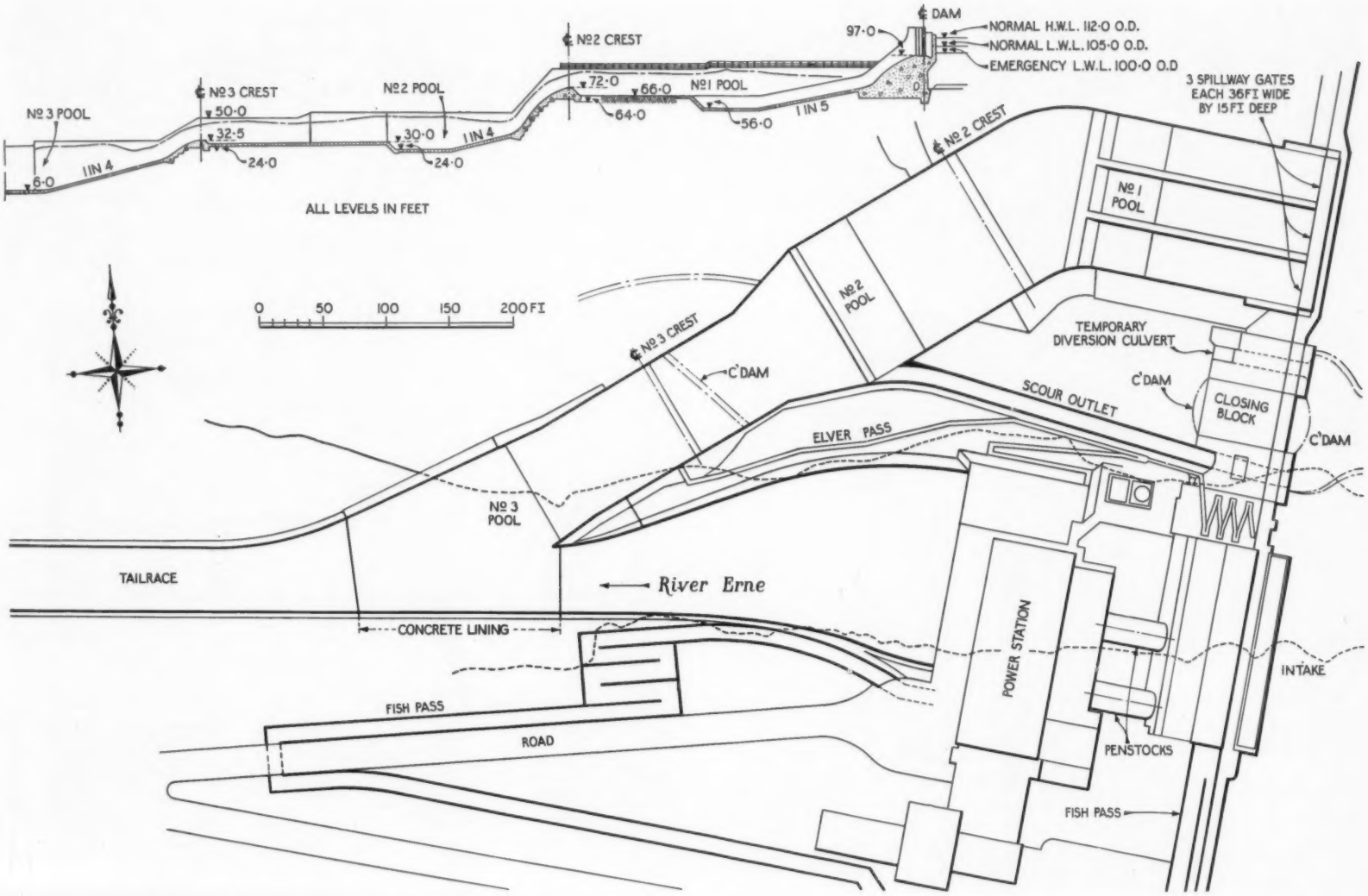


Fig. 1. Outline plan of Cathaleen's Falls power station, dam and spillway channel, with sectional elevation of the spillway channel

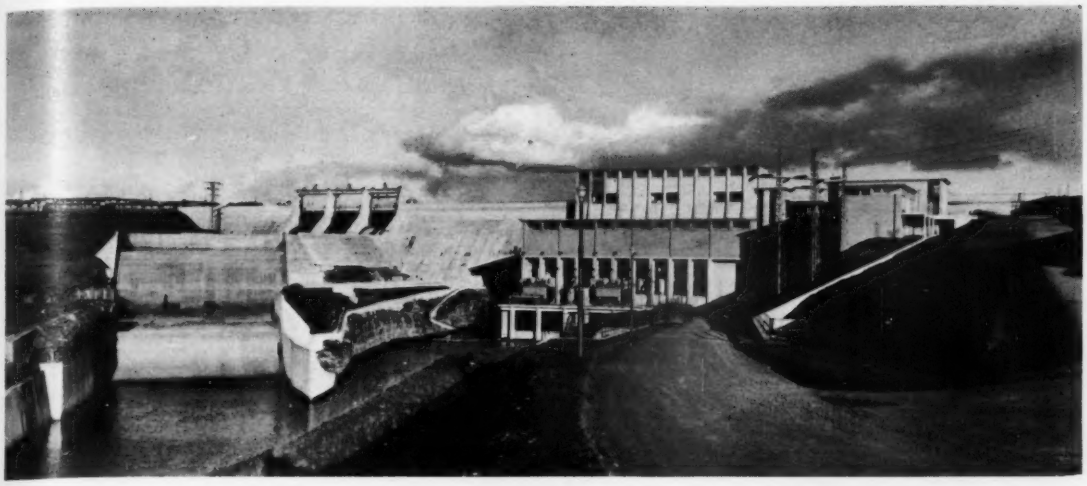


Fig. 2. Downstream view of Cathaleen's Falls power station

Cathaleen's Falls Power Station

These concluding articles on the Erne River development, Eire, are devoted to a detailed description of the Cathaleen's Falls station and associated works.

PART ONE

CATHALEEN'S FALLS, situated just above Ballyshannon, is the larger of the two stations constituting the Erne River development, and forms the administrative and control centre as well as being the point from which the electrical transmission system originates.

A view of the station is given in Fig. 2 and an outline plan is reproduced in Fig. 1. As stated in our first article, a mass concrete gravity dam has been constructed, 90 ft. high by 1,000 ft. long including earth embankments at the ends. The power-station intake structure is incorporated towards the left of the dam and feeds the station, lying just below the toe of the dam, by penstocks. At present the station houses two 22·5 MW sets, but the site has been arranged so that the station can be extended to accommodate a third similar set. To the right is a spillway of unusual design, carrying the water down in three stages, and a scour channel. A major civil-engineering operation was the cutting of a tailrace channel 4,500 ft. long, 48 ft. wide and 26 ft. deep between the station and Ballyshannon Bay.

Diversion Channel*

Throughout the Cathaleen's Falls site the prevailing rock is Lower Carboniferous limestone dipping at an angle of about 10° under about a foot of overburden and overlying a bed of gneiss. The Falls themselves took the form of a series of rapids, and were situated in a gorge, about 50 ft. wide, lying about 400 ft. above the centreline of the dam. Below the Falls the river gradually widened out again to its normal width of 150 ft.

Unlike the case of Cliff, it was decided at the outset to deal with the river by means of a diversion channel. This channel was cut in the north bank, where it embraced some permanent works, including part of the spillway channel, the culvert blocks and closing block of the dam, and the scour outlet channel. It was 50 ft. wide and about 20 ft. deep, the sides having a batter of 1 horizontal to 6 vertical.

Fig. 3 is a plan of the diversion channel showing the system of cofferdams. Work started in March 1946, and after stripping the overburden from the downstream end of the channel a 30 ft. wide cut was taken down to invert level at a gradient of 1 in 30. The face was then opened out to full width and carried forward up the channel.

Primary drilling was done with Ingersoll Rand X71 and DA35 drifters on FM2 wagon mountings, and secondary drilling with JA45 jackhammers. Blasting was effected almost entirely with Polar ammon gelignite electrically detonated with low-tension instantaneous and delayed-action detonators together with Cordtex fuse. Normally the complete width of the channel was blasted to its full depth using three rows of holes, about 20 ft. deep, parallel to the face and respectively 6, 12 and 18 ft. from it, the front-row detonators being instantaneous and the second and third rows having delays of one and two seconds. Alternatively the outside holes of each row were arranged to fire one second later than the remainder

* For a full account see a paper "River Diversions on the Erne Power Development—Part II. Cathaleen's Falls" read by G. Mahony, B.A., B.A.I., to the Institution of Civil Engineers of Ireland on December 5, 1949. Fig. 3 is reproduced from this paper.

Fig. 1. Outline plan of Cathaleen's Falls power station, dam and spillway channel, with sectional elevation of the spillway channel

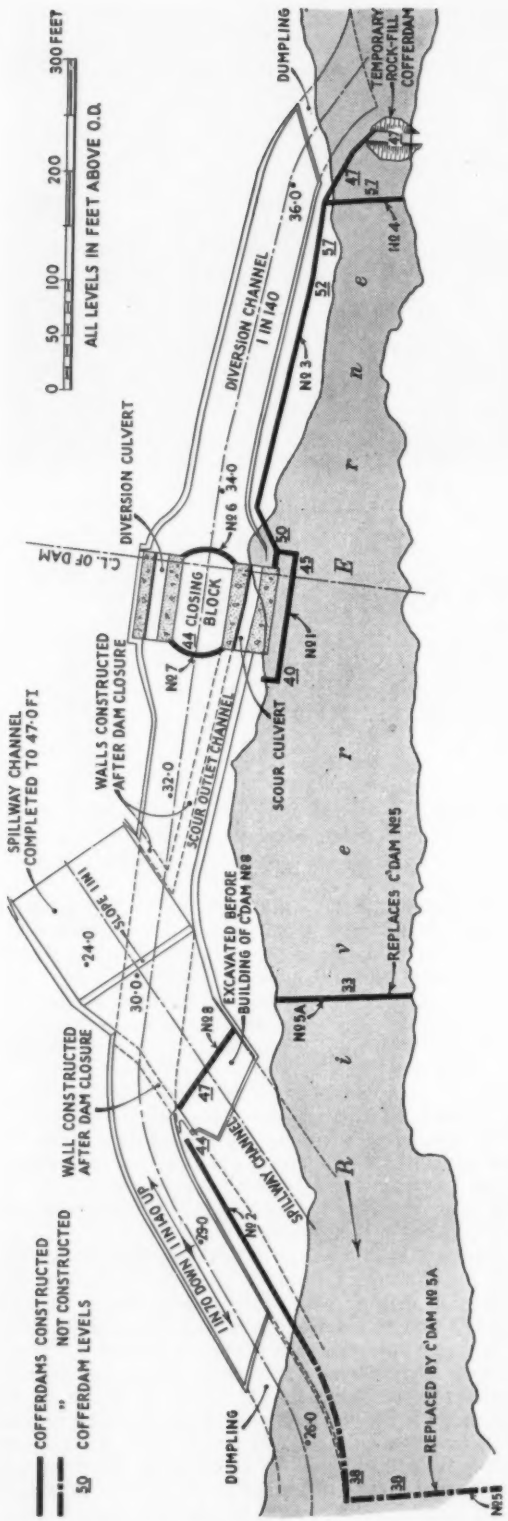


Fig. 3. Plan of the river-diversion procedure at Cathaleen's Falls

of the row and simultaneously with the row behind. Explosive consumption averaged 0·8 lb. per cu. yard of rock.

Where the sides had to be trimmed to exact profile —for instance, to reduce overbreak and consequent excess of concrete where the channel was lined—a line-drilling technique was employed. This consisted of drilling holes along the excavation payline at close centres—usually 1 ft.—the main face then being blasted to leave a fringe of rock from 2 to 4 ft. thick over the payline. This fringe was then stripped off along these perforations by lightly charging every fourth or fifth hole. On unrestricted faces an accurate break could be obtained by charging only one hole in six.

Overburden was removed by $\frac{5}{8}$ cu. yard Ruston-Bucyrus dragline and 6 cu. yard Blaw-Knox scrapers. Most of the rock excavation was accomplished by RB17 face shovels, one in the diversion channel proper and another in the spillway-channel excavation, which was opened out as soon as the diversion channel crossed its path. Trials were also made with a slusher, but the conditions were not suitable.

In the summer of 1946 advantage was taken of very low river flows to work on the river face of the inlet to the diversion channel, which was blasted down to grade and excavated by dragline.

Meanwhile work had been proceeding on the cofferdams, most of which were of concrete construction anchored by twist rods grouted into the foundation rock. No. 1 cofferdam was completed in November, but considerable difficulty was being encountered with No. 2 cofferdam as it was exposed to the flow of the river and had to be built in depths of water up to 12 ft.

Concreting of the permanent works in the diversion channel commenced in March 1947, and included the portion of the spillway channel affected by the diversion channel, the south wall of the scour outlet channel, and the culvert blocks of the dam. Upstream of the dam considerable leakage from the river was noted during flood, so the whole face next to the river bed was coated with Gunite. Gunite was also applied to the north face of the channel immediately downstream of the northern culvert block to protect it from scour after the dam was closed, the floor of the channel about 50 ft. downstream of both culverts being concrete lined for the same reason.

Widening of the downstream end of the channel was also commenced in March 1947, and the breakthrough was accomplished without difficulty, as owing to the gradient of the channel the water did not reach more than halfway up the tracks of the excavator.

To provide for closing the dam at a later date, skewbacks were formed in the corners of the culvert blocks to receive cofferdams Nos. 6 and 7, which were of the precast arch type.

Cofferdam No. 8 had to be built on the completed lining of the spillway channel and had to be removable with minimum damage to the permanent works. Timbers, 9 x 3 in., were set on edge on the invert slab to form a seating for the cofferdam, and for sealing to the walls two experimental types of waterstop were tried. One consisted of a 6 in. rubber strip concreted half into the cofferdam and half into the wall, the other consisting of Bitulac poured into a 9 in. x 4 in. groove down the wet face of the cofferdam and held in place by a timber cover. A minor leak developed in the rubber stop due to the insufficient length em-

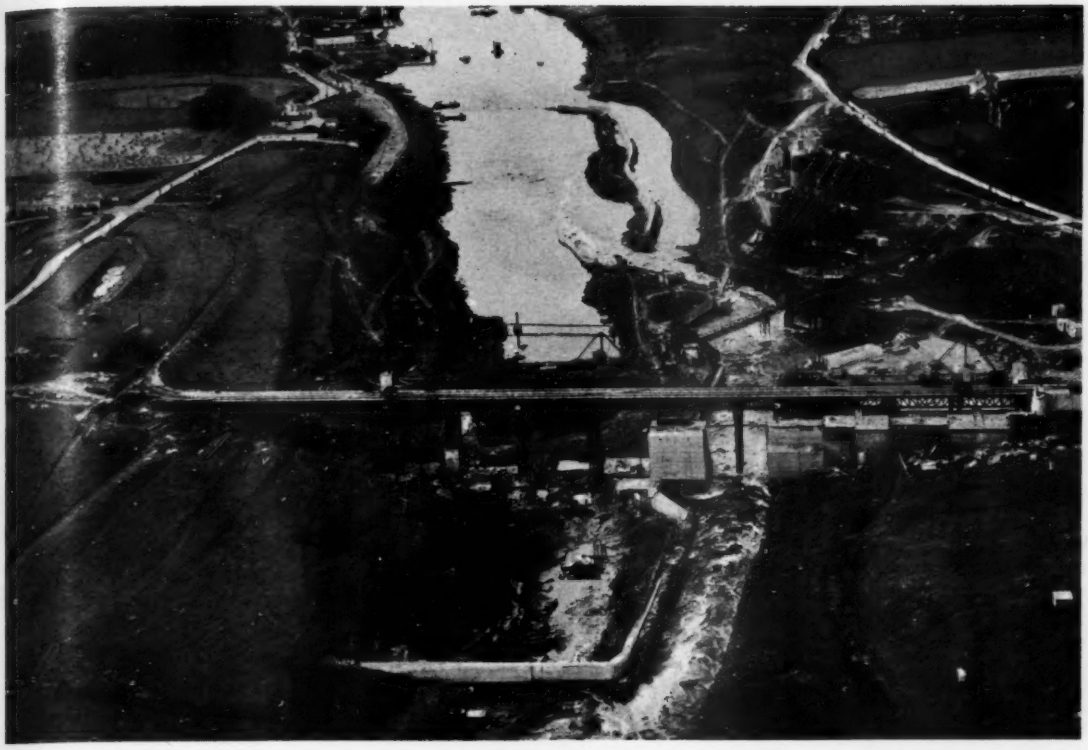


Fig. 4. Aerial view of the river diversion showing also the power-station excavation and the gantry used for building the dam

bedded and to poor bonding, but the Bitulac seal behaved satisfactorily although water rose to within two feet of the 18 ft. high crest of the cofferdam.

By the end of July all was ready to remove the dumpling barring the inlet to the diversion channel, but it was not until August 23 that the requisite low river flow of 1,800 cusecs was obtained. As the rock comprising the dumpling was shattered, it was deemed advisable to blast in a single operation. Two rows of holes 12 to 14 ft. deep at 3 ft. centres were drilled along the river face raking towards the river to follow the slope with 2 to 3 ft. of burden. Behind these, three rows of vertical holes were sunk at 3 ft. centres to a depth of 4 to 5 ft., and finally horizontal holes, 20 ft. long at 3 ft. centres, were drilled from the channel face to end close under the raking holes. The sides of the dumpling were line drilled at 1 ft. 6 in. centres. The north-side line drilling contained 5 lb. of explosive in every third hole, the raking holes 8 to 10 lb., the vertical holes 2 lb., and the horizontal lifters 18 lb., making a total charge of 1,150 lb. with Cordtex fuse and 10 instantaneous detonators.

Fig. 5. Looking down the spillway channel from the sluice-gate structure

No secondary blasting was needed, and the debris was drawn across the river channel by slusher to form a temporary barrier to enable No. 4 cofferdam to be built, which contained a 6×6 ft. wooden gate.

Two days after the breakthrough the river bed was exposed throughout its length, and it was noticed that a high ledge of rock traversed the bed just downstream of the power-station site, and afforded an ideal site to construct a cofferdam in the dry. Cofferdam No. 5A was therefore built at this

point, rendering unnecessary the completion of No. 2 cofferdam and the building of No. 5. The construction of both of these would have been difficult and failure would have lost a season's programme. Furthermore, it was no longer necessary to drain the toe of the spillway channel as the design had been modified.

Fig. 6. Looking down the tailrace channel from the power station. The fish ladder can be seen on the left, the elver pass in the right foreground, and the mouth of the spillway channel to the right centre

Dam Construction

We have already referred to the excavation of the power-station site when describing aggregate production in our first article, and the excavation of the dam site calls for little comment. An extensive programme of grouting the dam foundation was carried out on similar lines to those adopted at Cliff. Special deep grouting was required to seal off seepage from a small lough on the right bank, and a fissure in the foundation had to be followed down about 30 ft. by shaft before it was sealed off.

The dam was built in 18 blocks ranging from 42 ft. to 55 ft. 6 in. in width. On account of its length, fixed derricks, as used at Cliff, were rejected in favour of a structural-steel bridge spanning the site immediately downstream of the dam centreline. This bridge carried three lines of 2 ft. gauge track and two travelling derricks each lifting 3 tons at 85 ft. radius. Concrete was brought along the bridge from the central mixing plant in Blaw-Knox bottom-dump buckets.

At each end of the dam is an earth embankment section having a clay core consolidated above rock.

Salmon and elver passes have been constructed, of similar design to those at Cliff, but the salmon pass at Cathaleen's Falls has 77 pools and four outlet gates.

Spillway

The final design of the spillway channel, which can be seen in the general arrangement drawing, Fig. 1, was determined by model tests carried out by the Civil Works Department of the Electricity Supply Board at Trinity College, Dublin.* The headwater level ranges from 100 to 112 ft. O.D. and the tailwater level from 3·5 to 24·2 ft. O.D., and the spillway has been designed to carry the maximum known flood of 11,000 cusecs with the station shut down. Three 36 ft. wide sluices have been provided, and the maximum flood can be discharged through any two of them. An early investigation was undertaken to compare vertical-lift sluice gates and drum gates, and it was decided that in the prevailing conditions the advantages to be derived from the use of drum gates did not warrant the additional cost. Three 36 x 15 ft. Ransomes & Rapier fixed-roller sluices have therefore been constructed, the centre gate being fitted with a flap. They are electrically operated, and can be controlled either locally or from the control room, where their positions are indicated by Evershed transmitters. Three dam beams are provided, sufficient to fill any one opening and permit inspection of the gate.

The scour culvert is controlled by Glenfield & Kennedy hand-operated and counterweighted gates 12 ft. wide by 15 ft. high, the downstream gate being of the free-roller, and the upstream of the fixed-roller type.

When determining the general form of the spillway it was decided to take advantage of the configuration of the site by dividing the fall into three steps, the first to the general ground level of 68 to 80 ft. O.D., the second to the diversion-channel invert level of 30 ft. O.D., and the third to the tailrace at invert level of – 6 ft. O.D.

Tests were made on the models at discharges of 11,000, 7,000 and 3,500 cusecs in the spillway through three, and alternatively two gates equally opened. Further tests were made with various combinations of discharges through the spillway and the power station and with discharges of 3,500 and 1,800 cusecs in the scour culvert. Eventually it was found that the power-station discharges had no appreciable effect on conditions in the spillway, and it proved possible to make the appropriate allowance for this discharge by controlling the water level in the tailrace.

In the original design the bulk of the energy was to be dissipated in the first pool by means of a standing wave, the outflow from the second and third pools being spread over wide weirs arranged so that the nappes fell almost vertically into the pool beneath and were thereby cushioned. This proved unsatisfactory because the water swept across the second and third pools at high velocity and piled up on the opposite walls, so the layout was redesigned so that standing waves would be formed in the second and third pools also.

Tests were then conducted on the redesigned model to determine the most suitable detail arrangements. In the first pool conditions at the bend were very disturbed, and the water tended to pile up on the right-hand wall, but this was overcome by continuing the spillway piers as spur walls throughout the length of the pool. The minimum length of pool and the optimum height of weir No. 2 were also determined. To improve conditions in the second pool, the crest of this weir was redesigned with a fuller profile, a flume construction at the outlet of pool No. 2 was replaced

* For a full account see a paper "Tests on Models of the River Erne Power Scheme, Part II—The Spillway at Cathaleen's Falls Power Station" read by J. A. O'Riordan, M.A., B.E., A.M.I.C.E., on February 17, 1947, before the Institution of Civil Engineers of Ireland.

by a weir, 80 ft. wide, and pool No. 3 was increased in width from 60 to 80 ft. The scour outlet channel originally extended over the full width of the diversion channel, but the discharge piled up against the opposite wall of the spillway and the flow over weir No. 3 was very uneven. The channel was therefore reduced to 12 ft. in width, the remainder of the diversion channel being backfilled, and was trained round to deflect the discharge in the general direction of the centreline of the spillway.

These conclusions were then examined in the light of economic and constructional considerations. The centrelines were adjusted to shorten the spillway as far as possible without detriment to its performance, pool No. 1, except for the apron, was lowered bodily by 4 ft., and sloping side walls in pools 1 and 2 were made vertical. A third model was then constructed from which the actual design dimensions were determined.

To permit velocities above 10 ft. per sec. to be used, pools 1 and 2 are concrete lined throughout, and to allow for some disturbance where the spillway discharge enters the tailrace, the tailrace is also lined at floor and side over the region of the junction.

Tailrace

Model tests were also carried out at Trinity College, Dublin, to determine the design of the tailrace.* The basic problem was to control the discharge so that at the maximum flood of 11,000 cusecs and the lowest recorded tide of $+3\frac{1}{2}$ ft. O.D. the velocity in the tailrace would not exceed 10 ft. per sec. and the energy would be dissipated before the water emerged into Ballyshannon Bay. This would avoid the necessity for lining the tailrace and would prevent scour in the bay. On the other hand, the design had to be such that at the highest spring tide of $+17\frac{1}{2}$ ft. O.D., a flood discharge would not back up to the power station sufficiently to interfere with the performance of the turbines. These hydraulic requirements, of course, had to be balanced against the relative constructional costs of the various proposals.

As a result of preliminary design work it had been decided that the channel should be of trapezoidal section, 48 ft. wide at invert level, the sides having a batter of 1 horizontal to 6 vertical, and it was required to determine the invert level and the type of control device to be incorporated in the channel outlet.

The river ranged from 100 to 500 ft. wide between Ballyshannon Falls and the bay, and its natural bed was at 20 to 24 ft. O.D. from the foot of Cathaleen's Falls to Ballyshannon bridge, whence it dropped gradually to about 15 ft. O.D. at Assaroe Falls, falling steeply thence to the bay, the floor of which is at about -25 ft. O.D. Originally it was intended to excavate the channel to an invert level of ± 0 ft. O.D., but tests were carried out on invert levels of 0, -6 and -10 ft. O.D. Lowering the invert level would increase the cost of excavation but would reduce the amount of energy to be dissipated at the control point and would increase the available working head at the station. The best economic balance was found to be at -6 ft. O.D., and this figure was chosen.

Three types of control device were tested—a venturi flume, a broad-crested weir, and a sudden downward slope in the invert without any side contraction or rise in bed level. The third device was equivalent to no control, and would have given rise to velocities considerably above 10 ft. per sec., but would presumably have resulted in lower tailwater levels at the power station. Seeing that the economic balance was subsequently found to be in favour of an unlined channel this method of control became inadmissible, and the final choice rested between the weir and the flume.

From the hydraulic aspect there was not much to choose between the three methods of control tested, but the weir tended to produce the most reliable and uniform distribution of velocity near the bottom of

* For a full account see a paper "Tests on Models of the River Erne Power Scheme. Part I—The Tailrace," read by G. FitzGibbon, M.A., M.A.I., A.M.I.C.E., on February 17, 1947, before the Institution of Civil Engineers of Ireland.

Fig. 7. The weir at Assaroe Falls under construction

Fig. 8. Part of the tailrace side wall after blasting by the line-drilling technique

the section downstream of the standing wave. Furthermore the value of the taper of the side flare was less critical, and the disturbance caused by the weir was less violent than with the other methods, although the disturbance extended farther downstream. On hydraulic grounds, therefore, the weir was the most satisfactory. From an economic standpoint the balance was slightly in favour of the flume, but it was not sufficient to overweight the greater reliability of the weir, which was accordingly chosen. The weir was constructed at Assaroe Falls, near the outlet to the bay, and has a crest level of +6 ft. O.D. Downstream it is flared to give a width of 68 ft. and a bed level of − 16 ft. O.D., and the weir and flare are concrete lined.

Over most of its length the river bed consists of Lower Carboniferous limestone, and over this region a concrete cofferdam was built in sections down the approximate centreline of the river. The blasting and excavation of this channel through the heart of the township was a delicate operation, and blasting charges were limited to 50 lb. in any one round, and to amounts as low as 15 lb. in close proximity to concrete structures. Vertical holes were sunk at 6 ft. centres by Ingersoll-Rand wagon drills, and the charges fired by millisecond detonators, scatter from blast being controlled by nets. Line drilling at 1 ft. centres was employed to trim the sides. Spoil was loaded by 1 cu. yard scrapers into 1½ cu. yard tip wagons which were transferred by a travelling gantry spanning the tailrace to a 2 ft. gauge track at ground level where they were hauled to the spoil dump by diesel locos. The spoil was eventually used to fill up the portion of the river bed not occupied by the tailrace.

About 900 ft. of the channel is in boulder clay, and this section was excavated under water by a 43B Ruston excavator mounted on a pontoon. The spoil was put into 2 cu. yard tip-wagon bodies in a barge, which was towed to the bank by electric winch, and the bodies transferred to the track by a derrick. This section has an invert level of − 4 ft. O.D. at its centre, tapering to − 6 ft. O.D. at the ends, and side slopes of 1 horizontal to 3 vertical. The sides are protected by heavy rubble stone to above water level and hand-pitched heavy stone over the topmost portion.

(To be continued)

Loch Shin Project

The North of Scotland Hydro-Electric Board's Loch Shin project has been confirmed by the Secretary of State for Scotland. It is one of the Board's major projects and will produce about 151 kWh per year. The scheme covers a catchment area of over 250 sq. miles and will develop the resources of Loch Shin, its tributary streams, the River Cassley and the upper part of the River Bora. Four dams and five generating stations with a total installed capacity of 40 MW will be constructed. Loch Shin will be raised and enlarged by a dam across the narrows just north of Lairg. Incorporated in the dam will be a generating station discharging into the remaining small part of Loch Shin. A second dam will be built across the River Shin below the present outlet of the loch and water from this reservoir will be led by aqueduct to the main generating station near Inveran Hotel. Water from the upper River Brora will be diverted into the Shin catchment by a weir at Dalnessie and taken by aqueduct into the River Tirry. A generating station is also to be built near Creanich at the western end of Loch Shin and will use waters diverted from the upper River Cassley and its tributaries. Feur Loch will be enlarged by a dam and this water will be led by aqueduct to a generating station on the southern shore of Loch Merkland, near Garvault.

Another dam will form a storage loch by joining three small hill lochs and from this reservoir there will be an aqueduct to a generating station on the north shore of Loch Merkland east of the Stable Burn. The estimated capital cost of the scheme is £8,800,000.

Volta River Delegation to Canada

On September 9 a delegation is to leave the Gold Coast to visit some of the plants belonging to the Aluminium Company of Canada in order to gather information likely to assist in the prosecution of the Volta River project. The delegation will consist of Ministers of the Gold Coast Government and members of the national committee for the Volta River scheme. The delegation will be headed by Mr. K. A. Gbedemah, Minister of Commerce and Industry, and will include Mr. K. C. Tours, acting Minister of Finance; Mr. Kojo Botsio, Minister of Education; Mr. W. E. Ofori Atta, Mr. T. M. Kodwo Mercer, Dr. E. K. Kurankyi Taylor, and Dr. J. C. de Graft Johnson, national committee members; Mr. Kofi Baako, personal assistant to the Prime Minister; Mr. Gerald Plange, and Mr. S. M. Codjoe.

Abstracts from the World Technical Press

Damodar Valley Project

The various aspects of this important project are reviewed and discussed in the following articles which fill a special issue of the *Indian Journal of Power and River Valley Development* devoted to Damodar Valley Corporation (DVC):

"Something significant and mighty," a brief review of the works completed or under construction, by Mr. R. R. Diwakar, Governor of Bihar, p. 1, 2 pp., 1 f.;

"Message from the Chairman," by Mr. S. N. Mozumdar, p. 3, 2 pp., 1 f.;

"Damodar Valley Project," an outline, by Dr. B. C. Guha, p. 6, 6 pp., 1 map;

"Why a Steam Power Station," by Dr. Sudhir Sen, Secretary, DVC, p. 11, 8 pp., 2 ff.;

"DVC moves ahead," by A. M. Komora, Chief Engineer DVC, p. 20, 5 pp., 5 ff.;

"Land Reclamation in the Damodar Valley," by K. S. V. Raman, Head of Soil Conservation Department DVC, p. 23, 6 pp., 12 ff.;

"Bokaro Power Station," by P. K. Bhattacharya, Chief Electrical Engineer DVC, p. 29, 10 pp., 11 ff.;

"The Subarnarehka Basin, its Industrial Prospects," by V. R. Khedkar, Geological Division DVC, Director of Indian Bureau of Mines, p. 39, 4 pp.;

"Malaria Control Measures in Tilaiya and Konar Reservoirs," by Dr. B. P. Neogy, Chief Medical Officer DVC, p. 43, 3 pp.;

"DVC Power System," by J. N. Goswami, Deputy Chief Electrical Engineer, and K. Subramaniam, Commercial Engineer DVC, p. 45, 8 pp., 6 ff.;

"India and the TVA Method," Editorial, p. 56, 4 pp., 1 f. Proceeding from the statement "TVA is no longer a geographical institution; it represents a method," the editor draws a parallel between TVA and DVC, and strongly urges upon India's legislators to accept the TVA method as an effective instrument for unified resource development throughout the country. (*Indian Journal of Power and River Valley Development*, Vol. II, October 1952, DVC Number, 58 pp.)

New Developments in the Philippines

Two projects are now in course of construction in the Philippines, one at either end of the chain of islands, that is to say Luzon in the north and Mindanao in the south.

The characteristic feature of the Luzon project is the Ambuklao dam on the Agno River, which will be one of the largest and highest rockfills in the world (Fig. 1), requiring a volume of 8,324,000 cu. yards of material, coupled with a height of 430 ft. No diffi-

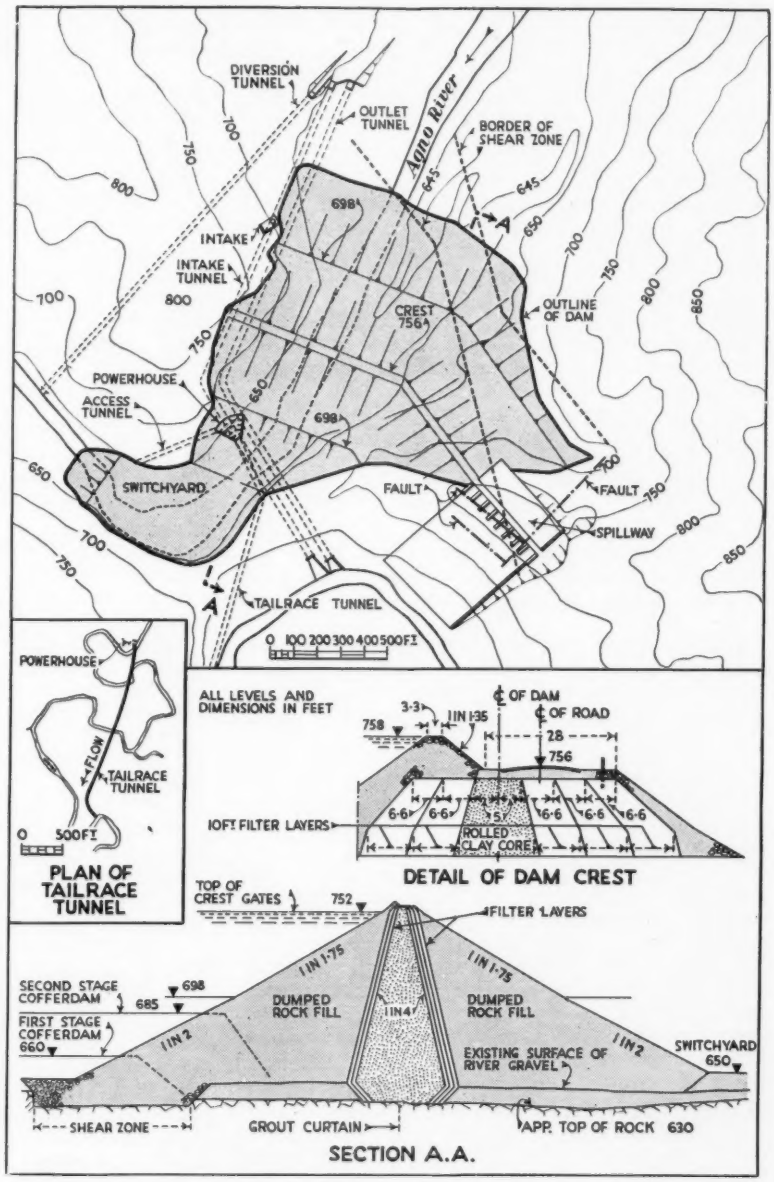


Fig. 1. Ambuklao dam on the Agno river

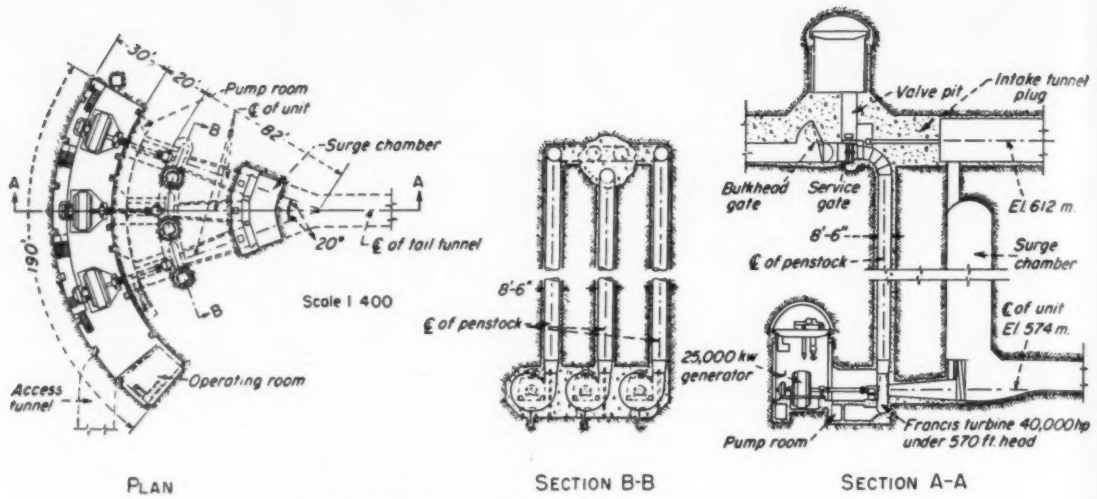


Fig. 2. Underground power plant at Ambuklao

culties in dam closure are expected, since the flow of the river during the dry season is extremely low. The underground power plant at Ambuklao is about 180 ft. below the base of the dam (Fig. 2); the generator room, 36 ft. wide, 54 ft. high and 215 ft. long, is radial in plan and will house three 25,000 kW units which will supply energy over 230,000 V lines to the nearby city of Baguio, the surrounding mining region, the Lingayen Gulf area and, later, Manila.

The second project under way in the southern island of Mindanao completely differs from Ambuklao, and consists merely of a low diversion dam (38 ft.) in the Agus River, an approach channel around Maria Cristina Falls, and a penstock dropping the water to a station at the foot of the falls. The initial power installation will consist of a single 25,000 kW generating unit; a similar unit will be added when industrial demand, at present non-existent, requires it.

Ambuklao will be the first of several projected dams and power plants on the Agno. *(Engineering News-Record,* April 16, 1953, p. 43, 3 pp., 6 ff.)

The Rance Tidal Power Station

An account is given of the investigations and studies which led in 1951 to the elaboration of this project.

Production is contemplated in a single ebb cycle with a single basin that generates energy during emptying; in other words, the basin is filled through gates by the tide water rising from the half-tide level, this being the minimum level of the previous generating period, to the high-tide level. After three hours' waiting, the water is released into the turbines under the head created between the top level of the basin and the ebb level of the sea, and energy is produced until the water levels upstream and downstream of the plant are even, which, whatever may be the tide coefficient, occurs at about half-tide level.

The barrage is to be set up north of the Rance estuary, upstream of the towns of St. Malo, St. Servan and Dinard, on a line connecting the Briantais head on the right bank with the Brebis head on the left bank. This site was selected for two main reasons. In the first place, as proved by extensive model and field measurements the Briantais-Brebis line cuts across the slowest currents, and secondly, the width of the estuary at this spot (800 m.) offers just enough room for the power house and the barrage.

The power house, equipped for a discharge of 4,000 cu. m. per sec., will have 26 generating sets, fairly similar in type to those used in low-head plants, and consisting each of a 14,000 h.p. Kaplan turbine coupled to a 8,500 kW three-phase alternator supplying energy at 10 kV. The turbine runners will be made of stainless steel. The Kaplan type of turbine was given priority because of its twofold regulation —opening of guide vane and adjustment of blade inclination—which enables the turbine to adapt itself satisfactorily to the very variable range of low heads and the widely fluctuating discharge characteristic of tidal plants.

The power house proper (Fig. 1), 47 m wide in the direction of the flow, will be erected in the middle and at the deepest spot of the estuary, which lies 11 m. below the level of the lowest tide. It will be flanked on either side by the barrage, the sluice gates of which will have an aggregate useful cross section of 2,500

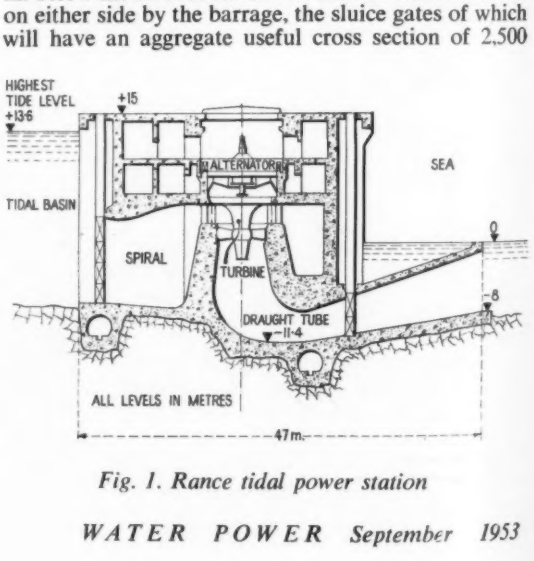


Fig. 1. Rance tidal power station

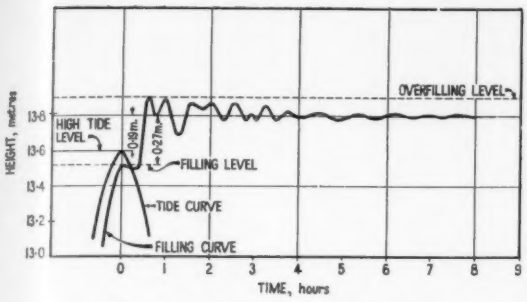


Fig. 2. Tide and filling curves

sq. m. These gates will operate automatically under the action of the tide current. The barrage will have no superstructure, and its crest 15 m. will be above the level of the lowest tides, or a mere 1·5 m. above the level of the highest tides.

Among the results of the comprehensive model tests carried out in connection with this project at the Laboratoire Dauphinois d'Hydraulique in Grenoble, attention is drawn to facts which might have been overlooked in theoretical investigations. It seems, for instance, impossible to contemplate in practice the simultaneous starting of 26 generating sets of the projected capacity, owing to the oscillations which a flow of about 4,000 cu. m. per second might cause in the estuary after the three hours' waiting period. A gradual switching-on of the sets, scattered over thirty minutes, is definitely much more favourable.

On the other hand, these model tests, when applied to the filling of the estuary basin at various openings of the sluice gates, revealed the occurrence of overfilling, which, owing to the inertia of the filling flow, causes the water level in the basin, after closure of the gates, to become stabilised at a height slightly above the filling level defined by the equalisation of the sea and basin levels (s. graph Fig. 2). (F. Voyer, Hydraulical Engineer, *Electricité*, Vol. 37, No. 192, March 1953, p. 63, 4 pp., 7 ff.)

The Harsprånget Generators

The whole of this issue is devoted to a description of the generators and associated equipment for Sweden's largest hydro-electric station at Harsprånget, described in the January 1952 issue of WATER POWER. The main articles in this issue are "Generators for the Harsprånget Power Station" by T. Strömberg, "Assembly of Big Generators" by N. Ringqvist, and "Regulators and Regulator Problems in the Harsprånget Power Plant" by S. E. Hedström, K. E. Johansson, G. Lindén and B. Olsson. A short article and a data sheet are also included relating to the Swedish 380 kV system. (*ASEA Journal*, March-April 1953.)

Generators for Hydro-Electric Plants

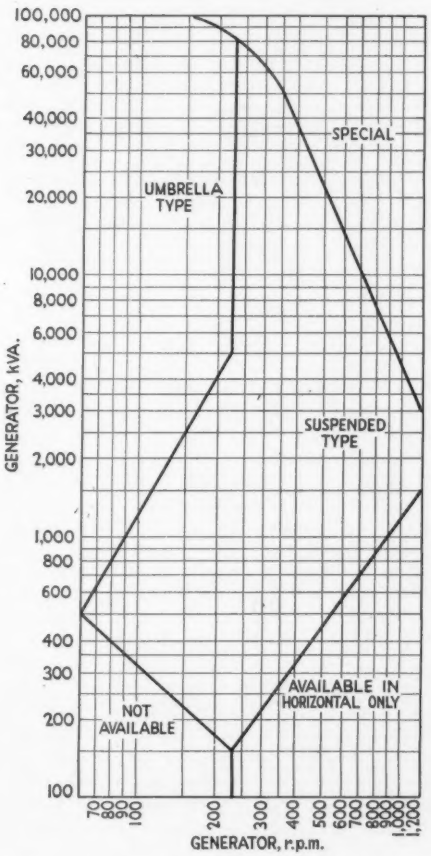
Owing to the diversity of natural conditions in hydro-electric schemes it is not practicable to standardise generators, and a new design is required for each station. Several general types are available, and the approximate field of application for each type is shown in Fig. 1.

Small high-speed generators are available in horizontal-shaft units only, but this is a matter of relative overall costs rather than of design difficulties. Larger horizontal units have also been used extensively, mainly with Pelton turbines, but the development of the vertical multi-jet impulse turbine has reduced the field for this type of generator.

Vertical settings offer hydraulic and other advantages over horizontal settings. A Francis or propeller-type runner can be set well below tailrace level to reduce cavitation, and an impulse-type runner can be set close to tailrace level to take full advantage of the available head. On the other hand the generator can be set at a safe elevation above flood level, and it is easier to support.

Vertical generators may be divided broadly into suspended and umbrella types. The suspended type, which is the earlier, has the thrust bearing and one guide bearing above the rotor and a second guide bearing below it. This results in a relatively large upper bearing housing and a lower housing that must be strong enough to support the weight of the rotating parts when the jacks are brought into play.

In umbrella-type generators the thrust bearing and guide bearing are located beneath the rotor, and there is no upper guide bearing. This construction requires a rotor of fairly large diameter to allow sufficient room to accommodate the bearing housing and to afford access for servicing the thrust bearing. For this reason, and also for reasons of physical stability, it is limited to speeds below about 225 r.p.m., and below



Fields of application of generators

5,000 kVA to progressively lower speeds. The umbrella-type generator offers important advantages over the suspended type in the reduced crane clearance required—and consequently reduced height of power house—and in many cases in the smaller size of crane.

In certain circumstances — particularly on the borderline between suspended and umbrella types, a modified umbrella type may be the solution. This carries an upper guide bearing to permit a higher runaway speed to be catered for without endangering the physical stability of the machine.

The article concludes with a discussion on alternator housings as related to cooling, fire protection, dust elimination, and the use of indoor or outdoor enclosure. (H. H. Roth, *Allis-Chalmers Electrical Review*, 1st quarter, 1953, p. 20, 7 pp., 12 ff.)

Headwater Development in Tennessee Basin

The Nantahala Power and Light Company (NPL), a subsidiary of Aluminium Company of America, is reaching far into headwaters for extra power. Until a year ago, NPL had six hydro dams on tributaries of the Little Tennessee River, above TVA's Fontana reservoir in western North Carolina; Cedar Cliff, the first of three more projects, went into service in August 1952. The second is Bear Creek, now being built, and the third is Tennessee Creek, a two-reservoir project for which the diversion and penstock tunnels are being driven. The Cedar Cliff generator has a rating of 7,500 kVA; Bear Creek and Tennessee Creek will have capacities of 10,000 and 12,000 kVA respectively. Generated power will be fed into the TVA system, which counts the Alcoa plant, Tenn., 100 miles westward, among its biggest power consumers.

Tuckasegee river development

The first two projects will include a single dam with combined diversion-penstock tunnels under an abutment. Tennessee Creek, somewhat more complicated, consists of two dams, each about a mile upstream from the confluence of two streams. The power house will be sited at the confluence, receiving its water from a diversion tunnel, which looks in plan like the letter Y. The outspread arms reach to intake points above the two dams, conducting water to a 2,400 ft. pipeline leading to the power house. The total tunnel length is 4,860 ft., and the dams are 140 and 180 ft. high respectively, but the head at the power house is no less than 520 ft.

Bear Creek has the highest dam. Its 223 ft. height and its 800 ft. of crest length will give it a completed volume of 1,000,000 cu. yards. Reservoir filling was due to begin in June, and dam operation scheduled for September this year. The Tennessee Creek project is expected to be completed about a year later.

The keynote of NPL's policy in this development is economy. The scheme must be a paying proposition, and to achieve this construction costs are kept as low as feasible; all dams are rockfill structures, and all tunnels are unlined. *(Engineering News-Record*, Vol. 150, No. 20, May 14, 1953, p. 51, 3 pp., 8 ff.)

American Dam Building

An account is given in two instalments of a study tour arranged by the Swiss Association of Engineers and Architects in connection with the centenary festivities of the American Society of Civil Engineers. This highly interesting report, while giving the views of a Swiss expert on American dam-building trends, covers in a comprehensive manner and with many excellent illustrations such major developments as Columbia River (Hungry Horse, Chief Joseph, Grand Coulée, Cabinet Gorge), Missouri (Garrison), T.V.A. (Fontana, Watts Bar, Kingston thermal plant), as well as New York's water supply (Downsville dam). (Dipl. Ing. A. Spaeni, *Wasser- & Energiewirtschaft*, Vol. 45, No. 2, February 1953, p. 17, 10 pp., 15 ff.; No. 3, March 1953, p. 39, 9 pp., 15 ff.)

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Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

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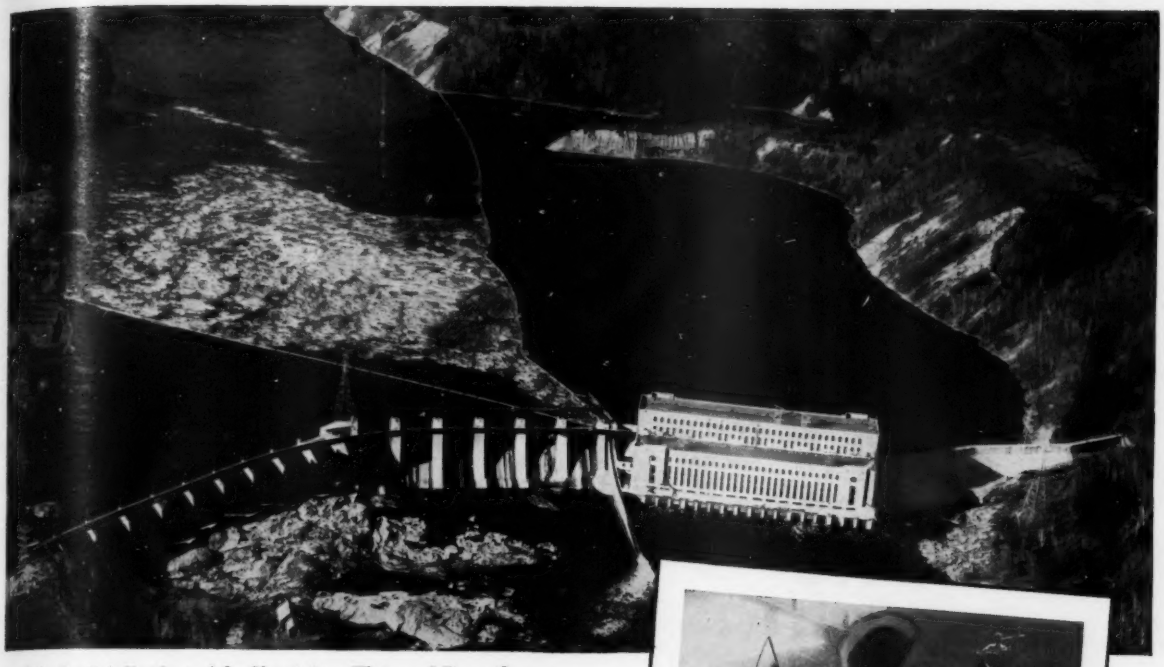

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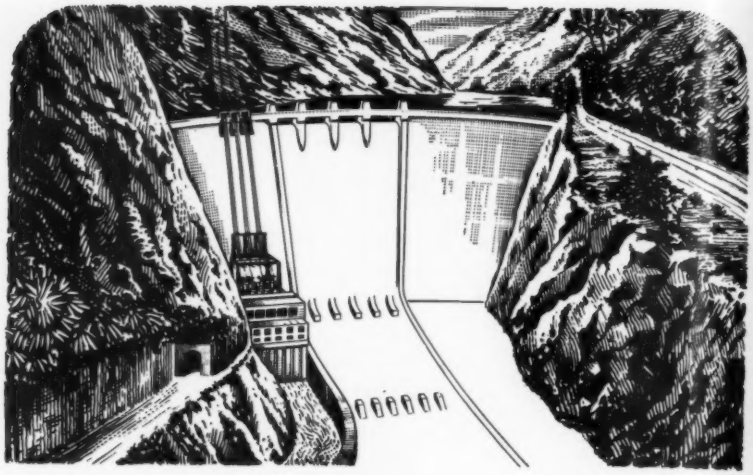

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Top: Artist's impression of the Los Peares Power Station, North-west Spain.

Left: Stator (under construction, in the BTH works) for one of the three vertical waterwheel-driven alternators (62,400 kVA., 11,000 volts, 3-phase, 50 cycles, 214 r.p.m.) to be installed in the above Power Station.

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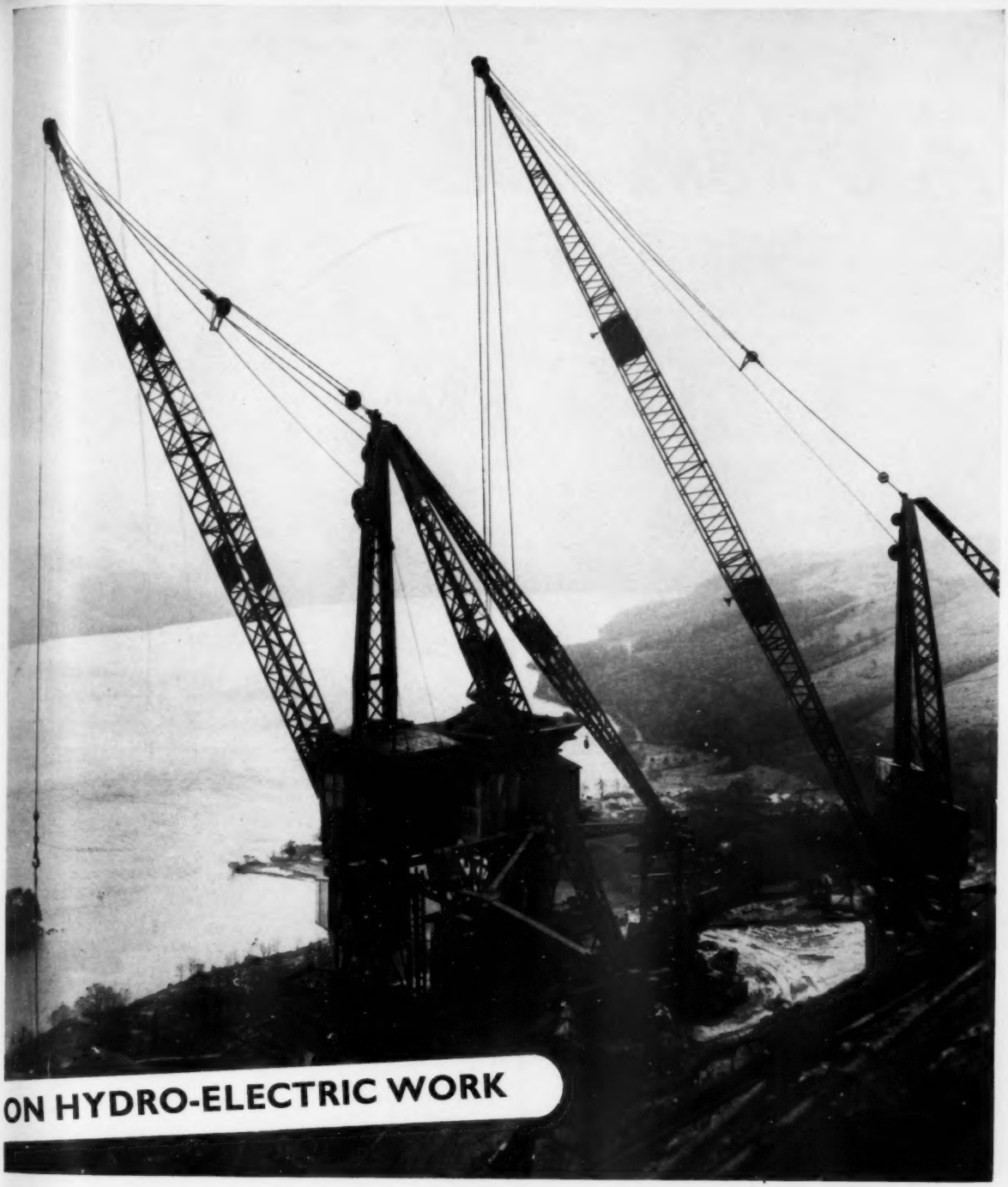

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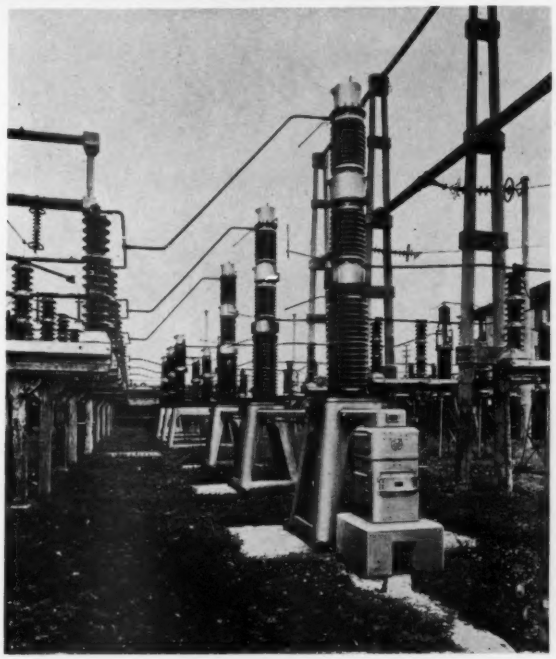

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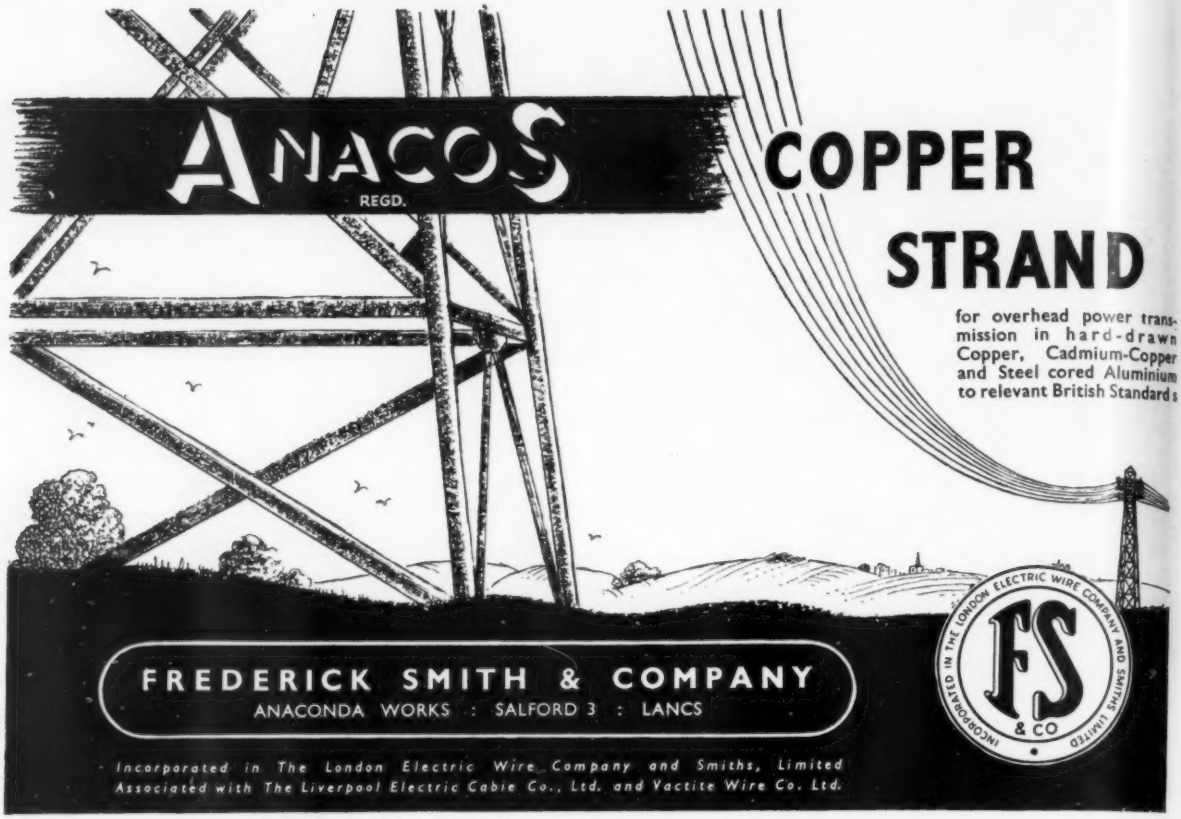
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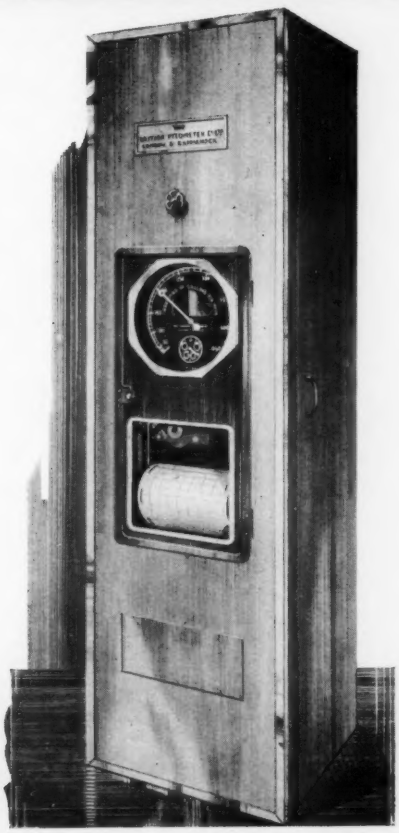

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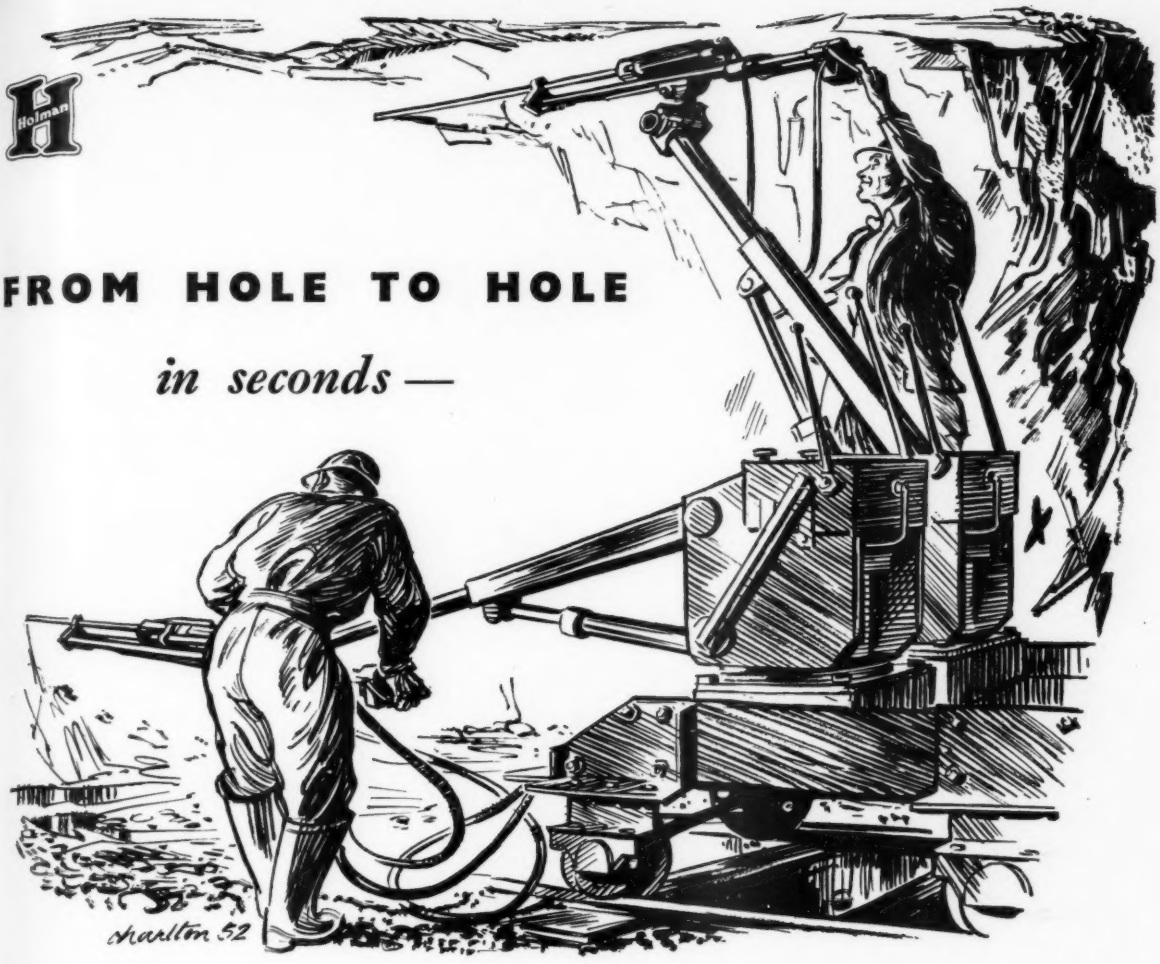

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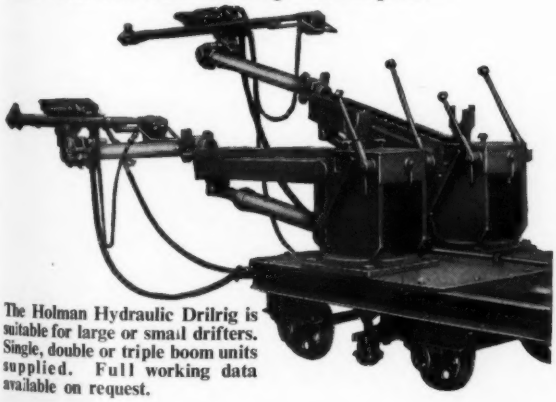

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